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PEACH HARVESTING AND STORAGE INVESTIGATIONS[1]

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Peach production in the Okanagan Valley of British Columbia is undergoing a period of rapid expansion. In 1942 the peach crop amounted to almost 1,000,000 crates, more than 4 times the production in 1933. A recent survey shows approximately 66,000 peach trees under 5 years of age and 82,000 trees from 6 to 10 years old. With due consideration for the removal of older peach trees and undesirable varieties, the increase in peach tree population has amounted to over 30% in the past 5 years. New peach orchards have been planted in more favourable locations, and tested varieties are being used which will reduce the hazards of production and result in heavier crops of peaches in the near future.

In order to deliver this increasing tonnage to fresh fruit markets and processing factories in attractive condition greater attention must be paid to harvesting and storage procedures. Peaches which are picked immature fail to develop good quality, whereas those which are left too long on the trees become soft and unfit to withstand commercial handling. Cold storage serves to hold fruit in good condition awaiting market requirements, retards ripening, and lengthens storage life, but only up to a certain point. Peaches held in cold storage too long lose their capacity to ripen, and suffer low temperature breakdown.

Low temperature breakdown as it occurs in Okanagan grown peaches varies somewhat with the variety and the season. With the earlier varieties such as Rochester and Vedette, the fruit tends to become dry, fibrous, and mealy, losing its juicy texture. A transverse section of the flesh shows a browned flushed area around the periphery which gradually extends inwards. When held at room temperature after removal from cold storage the fruit remains in a rather firm condition and does not soften normally, but finally breaks down and becomes mushy. With the J. H. Hale and Elberta varieties, the peaches upon removal from storage are firm and attractive in appearance, but after a few days at 65° F. become soft and spongy, discoloured in the flesh, stringy and coarse in texture, and quite inedible. They are particularly deceiving as their outward appearance upon removal from storage gives no indication of their true internal condition.

It was primarily to secure information regarding means of delaying and, if possible, preventing the onset of low temperature breakdown in Okanagan grown peaches that the experiments reported in this paper were undertaken.

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REVIEW OF LITERATURE

Breakdown in cold stored peaches has been reported upon by several investigators. Harding and Haller (9) found that the first indication of breakdown was a water-soaked appearance around the stone. In later stages, the water-soaked areas became larger and turned brown, and eventually all the flesh became brown and mealy. In South Africa, Davies *et al.* (4) mention two types of peach breakdown. With Type A the flesh becomes mealy and discoloured with a poor or objectionable flavour, in which case the fruit is described as "wooly". Type B, which is not as common, is characterized by a translucency of the flesh around the stone, which may extend to the skin and cause tissue discolouration, although affected fruit is usually juicy and of good flavour.

Breakdown in peaches results from over-storage at temperatures lower than 50° to 55° F. A storage temperature of 32° for peaches has been found by Harding and Haller (10, 11), Haller and Harding (9), Fisher and Britton (8), Smith and Willison (14), Adam (1), Davies *et al.* (4, 5) to retard development of breakdown as compared with storage at 36° and 40° F. Although the recommended storage temperature for peaches is 32° F., breakdown occurs in fruit held at this temperature after periods of 1 to 5 weeks depending on variety and season (11, 15, 8). It is probable that growing temperatures at the time the fruit matures play an important role in determining susceptibility to low temperature breakdown, for Fisher and Britton (8) and Willison (15) report quicker development of breakdown in varieties such as Hale and Elberta which mature late than in varieties such as Rochester and Vedette which mature early. Furthermore, British Columbia grown Elberta and Hale develop breakdown after 1 to 2 weeks at 32° F., whereas the same varieties grown under the more southern climate of Virginia are reported by Harding and Haller (11) to remain in good condition in 32° F. storage for 3 to 4 weeks.

Davies *et al.* (4, 5, 6) report that with white fleshed peaches grown in South Africa, breakdown (woolliness) may be controlled successfully by pre-ripening the fruit before placing it in cold storage. The higher the pre-ripening temperature the shorter is the period of delay necessary to control breakdown. Thus at 75° F. a period of 2 to 3 days is required to reduce breakdown to reasonable proportions whereas it takes 4 or more days at 65° F. and 8 or more days at 50° F. (5, 6). Davies *et al.* (6) did not obtain as good response from delayed storage in controlling breakdown with Elberta as they did with other varieties. Three days of pre-ripening at 65° F. followed by storage at 34° prolonged keeping life at least 1 week as compared with fruit stored immediately at 34° F. Fisher and Britton (8) report that development of breakdown in yellow fleshed peaches is delayed by deferred storage treatment.

In a recent study of "woolliness" in Peregrine peaches (white flesh), Reyneke (13) from South Africa states that from time of picking to the final stage of eating ripeness, the fruit passes from a firm juicy condition to a temporary juiceless condition and finally to a juicy eating condition. Fruit placed in cold storage when in the half-ripened juiceless condition develops "woolliness", whereas fruit placed in cold storage in the initial or final "juicy" stages ripens normally, free of "woolliness".

FIGURE 1. Peach orchard in the Okanagan Valley of British Columbia.

FIGURE 2. Type of tree from which peaches used in these experiments were harvested.

It is reported from Australia (3) that at 34° F. storage life of peaches was increased from 3 weeks to 4 and 6 weeks respectively by storage in atmospheres containing 5 and 10% carbon dioxide, that controlled atmosphere fruit ripened almost as well as that stored in air, but that overstored peaches developed a fermented flavour on ripening. Huelin *et al.* (12) from Victoria, Australia, report that while the average cold storage life of peaches at 32° F. is about 6 weeks, storing in controlled atmospheres containing 8 to 10% carbon-doixide lengthened the storage period by about 10%. Allen and Smock (2) also report that exposure of J. H. Hale peaches for 6 days to 15% carbon dioxide at 45° F. retarded ripening as compared with air-stored checks, and that quality was excellent. Gerhardt *et al.* (7) found that with J. H. Hale and Elberta peaches held in 10 or 20% carbon dioxide at 36° F. or 45° F., colour development and softening were retarded in storage, and the fruit took slightly longer to ripen than checks stored in air, but total keeping life of treated fruit was similar to that of untreated fruit. Fisher and Britton (8) obtained discouraging results from storage of Rochester, Vedette and Valiant peaches in an atmosphere of 7.5% of carbon dioxide at 40° F.

EXPERIMENTAL

Experiments were conducted at the Summerland Experimental Station in 1940 and 1941 to secure information concerning the influence of maturity at picking and length of delayed storage period on the behaviour of cold stored peaches.

Seven varieties of peaches, Rochester, Golden Jubilee, Vedette, Valiant, Veteran, Elberta, and J. H. Hale were picked both mature and immature and stored with and without pre-ripening treatment at 40° and 32° F. Records were taken of firmness, skin and flesh colour, and soluble solids content at picking time. Removals of peaches from cold storage to a 65° F. ripening room were made at weekly intervals to determine texture and quality of the fruit and evidence of low temperature breakdown. In addition to firmness and quality observations, determinations were made of respiration intensity and soluble pectin formation during ripening.

A further experiment was conducted to secure information concerning the influence of carbon dioxide on the storage life of Rochester and J. H. Hale.

Characteristics of Mature and Immature Peaches

In order to provide an accurate description of the condition of the fruit at the two stages of harvesting maturity used in these studies, records were made of flesh and skin colour, firmness and soluble solids content. The colours were taken on the unblushed side of the fruit using Ridgway's Colour Standards, soluble solids determined with a Zeiss refractometer, and firmness ascertained by means of a Ballauf pressure tester using both the 5/16-inch and 7/16-inch plungers on the unpared flesh of the fruit.

Some of the results secured are presented in Tables 1 and 2.

TABLE 1.—SKIN COLOUR, FLESH COLOUR AND FIRMNESS OF MATURE PEACHES, 1940

Variety	Date of harvest	Skin colour	Flesh colour	Firmness in pounds	
				$\frac{5}{16}$" point	$\frac{7}{16}$" point
				lb.	lb.
Rochester	July 29	Straw yellow	Mustard yellow	15.7	22.6
Golden Jubilee	Aug. 2	Straw yellow	Straw yellow	14.3	23.3
Vedette	Aug. 9	Amber yellow	Amber yellow	16.2	21.8
Valiant	Aug. 10	Straw yellow	Amber yellow	14.7	25.3
Veteran	Aug. 9	Mustard yellow	Amber yellow	15.8	19.8
J. H. Hale	Aug. 16	Naples yellow	Maize yellow	16.3	25.1
Elberta	Aug. 29	Naples yellow	Maize yellow	18.8	25.3

TABLE 2.—SKIN COLOUR, FLESH COLOUR, FIRMNESS AND SOLUBLE SOLIDS CONTENT OF PEACHES, 1941

Variety	Mature				Immature			
	Skin colour	Flesh colour	Firmness $\frac{5}{16}$" point	Soluble solids	Skin colour	Flesh colour	Firmness $\frac{5}{16}$" point	Soluble solids
			lb.	%			lb.	%
Rochester	Chamois	Amber yellow	14.9	12.1	Deep colonial buff	Barium yellow	19.7	11.5
Vedette	Barium yellow	Citron yellow	15.7	11.1	Light dull green-	Citron green yellow	19.1	10.5
J. H. Hale	Colonial buff	Naples yellow	15.8	11.1	Primrose yellow	Barium yellow	18.8	10.9
Elberta	Reed yellow	Barium yellow	16.7	11.4	Deep sea-foam green	Reed yellow	21.2	10.8

From the data presented in Tables 1 and 2 it is apparent that there were slight differences in the colours of "mature" peaches in 1940 and 1941. Nevertheless in both years the fruit of all varieties when classified as "mature" showed no green shades but rather the warmer shades of yellow in both skin and flesh. Picked at this stage the fruit was in good firm handling condition as shown by the pressure tests. It will be noted that the firmness of mature samples averaged from 14 to 18 lb. with the $\frac{5}{16}$-inch plunger and from 20 to 25 lb. with the $\frac{7}{16}$-inch plunger.

With regard to the fruit classed as "immature", Rochester and J. H. Hale had yellowish skin and flesh colour, whereas Vedette and Elberta were still tinged with green. Using the $\frac{5}{16}$-inch plunger the immature fruits averaged about 20 lb. in hardness. Differences in percentage of soluble solids between mature and immature peaches were small.

Influence of Maturity and Storage Treatments on Keeping Life of Peaches

Immediately after picking, the fruit was taken to a packing house and packed in dry wraps in standard peach boxes. At least one box of each variety was placed at once under each of the following conditions: 65° F. ripening room, 40° F. storage and 32° F. storage. In each of these rooms the atmospheric humidity was maintained close to 85%. Additional boxes of comparable fruit were delayed for from 1 to 5 days on the packing house floor before being placed under refrigeration. In the packing house, temperatures ranged from 60 to 80° F. when mid-season varieties such as Rochester and Vedette were being picked, and from 60 to 65° F. at the time J. H. Hale and Elberta were picked. Relative humidity was about 50% in the packing house throughout the harvesting season.

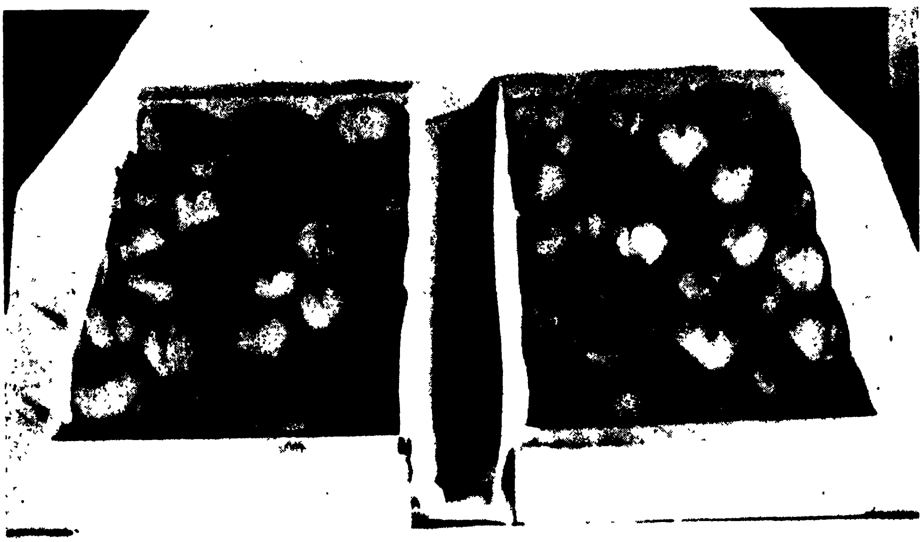

FIGURE 3. Twenty-pound double layer crate in which peaches used in these experiments were packed.

As previous work (8) had indicated that the effectiveness of delayed storage was dependent on the degree of ripeness attained by the peaches before they were placed under refrigeration, at least 1 box of each variety and each maturity was held in the packing house until the fruit had softened to a pressure of 12 to 10 lb. as measured by the 5/16-inch point on the Ballauf pressure tester. It was thought that at this firmness the fruit would have reached a stage of pre-ripening sufficient to retard the onset of low temperature breakdown but would still be firm enough to withstand commercial handling. The length of delay necessary to secure the required degree of softening was influenced by the maturity of the fruit when picked and also by variety. Data substantiating this statement are presented in Table 3.

TABLE 3.—SOFTENING OF PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	Firmness by pressure test using $\frac{5}{16}$-inch point									
	Peaches stored at once					Peaches stored after delay*				
	At picking	Weeks at 32° F.				At picking	Weeks at 32° F.			
		2	3	4	5		2	3	4	5
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Mature										
Rochester	14.9	9.4	9.4	9.0	8.2	9.6	6.5	6.2	4.7	4.5
Vedette	15.7	15.2	9.8	9.8	10.0	12.0	7.3	6.9	6.4	6.6
J. H. Hale	15.8	15.4	14.3	Breakdown		9.1	8.7	9.5	Breakdown	
Elberta	16.7	15.0	14.6	Breakdown		9.9	9.7	10.4	Breakdown	
Immature										
Rochester	19.7	16.7	16.7	15.4		11.0	7.7	7.0	6.2	5.2
Vedette	19.1	16.3	16.3	15.1		12.6	8.6	6.9	8.0	4.5
J. H. Hale	18.8	18.5	18.5	Breakdown		12.1	8.3	7.6	Breakdown	
Elberta	21.2	21.2	19.7	Breakdown		11.8	10.9	11.4	Breakdown	

* Delay in packing house 1 day for mature and 2 days for immature Rochester and Vedette, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

The data presented in Table 3 indicate that the Rochester and Vedette varieties softened very rapidly when held at packing house temperatures prevailing at time of harvest. In fact fruits of these varieties picked in the mature condition with a hardness of 16 to 15 lb. softened about 4 lb. in 1 day with the result that 24 hours after harvest they tested 12 to 10 lb., indicating that the desired amount of pre-ripening had taken place. Similarly immature fruit of these varieties picked with a hardness of 20 to 19 lb. softened to a test of 13 to 11 lb. in 2 days. With J. H. Hale and Elberta, softening proceeded more slowly, mature fruit reaching the desired condition of pre-ripening in about 2 days and immature fruit in 5 or 6 days.

From Table 3 it is also evident that the peaches continued to soften during storage at 32° F. In fact Rochester and Vedette softened quite materially with the result that fruit picked in the mature condition and delayed 1 day before storage was practically eating ripe after 4 weeks in cold storage. In contrast, J. H. Hale and Elberta softened slowly for the first 2 weeks in cold storage and then developed low temperature breakdown.

Samples of fruit receiving the various storage treatments were removed from the 40 and 32° F. rooms to a 65° F. ripening room at weekly intervals. Observations were then made daily to determine time required to reach eating ripeness, time to become over ripe, development of quality and prevalence of low temperature breakdown. Some of the data secured are presented in Table 4.

It will be noted from the data incorporated in Table 4 that with all varieties studied the length of time that the fruit could be held at 32° F. or 40° F. without initiating low temperature breakdown was comparatively short. In peaches held at 32° or 40° F. for more than 5 weeks, breakdown invariably developed regardless of whether the fruit was held for 1 or more days in the packing house prior to cold storage.

TABLE 4.—EFFECT OF STORAGE TREATMENT ON BREAKDOWN OF PEACHES

Maturity and variety	Number of weeks storage before onset of breakdown					
	1940				1941	
	Immediate 32° storage	Delayed* 32° storage	Immediate 40° storage	Delayed* 40° storage	Immediate 32° storage	Delayed* 32° storage
	weeks	weeks	weeks	weeks	weeks	weeks
Mature						
Jubilee	2	3	1	3		
Rochester	3	5	2	3	4	5
Vedette	2	3	2	4	3	4
Valiant	3	4	2	4		
Veteran	2	2	2	2		
J. H. Hale	2	2	2	4	1	2
Elberta	1	2	1	2	1	2
Immature						
Jubilee	2	3	2	3		
Rochester	3	3	3	2	4	5
Vedette						
Valiant	2	4	2	4		
Veteran	2	2	1	1		
J. H. Hale	2	3	2	4	2	2
Elberta	1	2	1	2	1	3

* Delay in packing house 1 day for mature and 2 days for immature Jubilee, Rochester, Vedette, Valiant, and Veteran, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

With fruit which was cold stored immediately, the period at low temperature necessary to initiate breakdown was materially shorter than when the fruit was subjected to a short pre-ripening period before placing in cold storage. Thus a delay of 1 or 2 days in the packing house made it possible to keep both mature and immature fruit of the mid-season varieties Golden Jubilee, Rochester, Vedette and Valiant from 1 to 2 weeks longer in cold storage than was possible when the fruit was placed in cold storage within a few hours after being picked. With the Veteran variety delayed storage failed to lengthen storage life, and with J. H. Hale and Elberta delays of 2 to 3 days for mature and 5 to 6 days for immature fruit were not always effective in retarding the onset of breakdown. Furthermore, even when ideal pre-ripening treatments were given, these varieties often remained in marketable condition as long when held at prevailing packing house temperatures as when subjected to cold storage treatment. Data supporting this statement are presented in Table 5.

From the figures in Table 5 it is evident that the marketable life of mid-season varieties such as Rochester and Vedette was materially lengthened by cold storage, especially when appropriate pre-ripening treatment was given. On the other hand with J. H. Hale and Elberta, cold storage even when preceded by a delay at packing house temperature, was not very effective in prolonging storage life. In fact these varieties, which keep well for several weeks at packing house temperatures, have proved so subject to low temperature breakdown when grown under British Columbia conditions, that it appears advisable to keep them away from cold storage.

TABLE 5.—EFFECT OF STORAGE TREATMENT ON LIFE OF PEACHES

Maturity and variety	Total days in marketable condition, including periods in packing house, under refrigeration and in 65° ripening room						
	1940					1941	
	65° F. room	Imme-diate 32° storage	Delayed 32° storage*	Imme-diate 40° storage	Delayed 40° storage*	Imme-diate 32° storage	Delayed 32° storage*
	days	days	days	days	days	days	days
Mature							
Jubilee	8	18	24	11	24		
Rochester	11	27	39	19	24	34	38
Vedette	12	24	25	19	31	39	34
Valiant	13	29	34	20	34		
Veteran	13	22	22	19	17		
J. H. Hale	33	21	22	23	39		27
Elberta	26	15	15	14	22		14
Immature							
Jubilee	14	20	27	20	26		
Rochester	18	30	30	27	20	34	41
Vedette	21					35	45
Valiant	18	22	33	22	34		
Veteran	14	24	25	13	17		
J. H. Hale	35	21	31	24	39		31
Elberta	33	17	23	14	22		32

* Delay in packing house 1 day for mature and 2 days for immature Jubilee, Rochester, Vedette, Valiant and Veteran, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

The data presented in Tables 4 and 5 indicate that with respect to breakdown and length of marketable period the fruit stored at 40° F. behaved much like that stored at 32° F., with the advantage, if any, in favour of 32° F. storage.

From Tables 4 and 5 it is also evident that fruit picked in the condition described in this paper as "immature" tended to have a slightly longer storage life than that described as "mature" but the differences were small. Furthermore, the quality of the fruit picked "mature" was greatly superior to that picked "immature".

It was also observed that with mid-season varieties such as Rochester and Vedette a short pre-ripening treatment prior to cold storage resulted in reduced astringency, improved texture, and enhanced quality.

Influence of Maturity and Storage Treatments on Soluble Pectin Formation

Information concerning the changes in pectic materials which take place in Rochester, Vedette, J. H. Hale, and Elberta peaches during the ripening period was secured by determining the content of soluble pectin in juice from freshly picked peaches and from similar samples kept for various periods of time in the packing house and in cold storage. In making the determinations the Carre and Haynes (2a) method was used. Some of the data secured are presented in Table 6.

TABLE 6.—SOLUBLE PECTIN FORMATION IN PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	Soluble pectin in 16 cc. of clarified juice												
	When picked	After holding in packing house for				After holding in 32° F. storage for				After holding in packing house and 32° F. storage for			
		1 day	2 days	3 days	5 days	14 days	21 days	28 days	42 days	14 days	21 days	28 days	42 days
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
Mature													
Rochester	7	33				73			74	134			197
Vedette	24	43	80			36		74		114		148	
J. H. Hale	32		87			38	45			109	113		
Elberta	15		95			92	124			116	121		
Immature													
Rochester	1		80			13			39	121			208
Vedette	3		37	83		10		34		135		158	
J. H. Hale	9				127	36	40			119			
Elberta	5				170	21	53			168	165		

NOTE.—Temperatures in the packing house ranged between 70 and 80° F. when Rochester and Vedette were picked and between 60 and 65° F. when J. H. Hale and Elberta were picked.

It will be noted that with all 4 varieties at time of picking the mature fruit contained much more soluble pectin than the immature fruit. Soluble pectin values increased very rapidly in both mature and immature samples held at packing house temperatures. At 32° F., hydrolysis of insoluble protopectin to the soluble form proceeded at a much slower rate with the result that less soluble pectin had been formed after 2 weeks at 32° F. than after 2 days at packing house temperatures.

With peaches which were subjected to a pre-ripening treatment of 1, 2 or 3 days at packing house temperatures, formation of soluble pectin continued after the fruit was placed in 32° F. storage. On the other hand, with the immature samples of J. H. Hale and Elberta which were held at packing house temperatures for 5 days, formation of soluble pectin had apparently reached its peak and there was a slight decrease after transfer to 32° F. storage. This was probably due to conversion of some soluble pectin to pectic acid.

Comparison of data presented in Tables 3 and 6 indicates that there was a close correlation between formation of soluble pectin and softening of flesh.

Influence of Maturity and Storage Treatment on Respiration

Respiration intensity is considered one of the most reliable indicators of physiological changes occurring in fruit tissue. To provide information concerning the physiological changes occurring in the peaches used in these experiments, respiration determinations were made on mature and immature samples held at packing house temperatures and after being placed in cold storage. For these experiments about 2·5 kilograms of peaches were enclosed in a 4-gallon can with a wide friction-type lid. Two copper tubes were soldered into opposite corners of the tin, one for air intake, the other as the outlet. A constant stream of air was pulled through the tins

over the fruit at a rate of 7 litres per hour, by attaching the respiration unit, with a flow meter, to a constant pressure vacuum line. At intervals, a Truog absorption tower containing glass beads and 50 cc. of 0·114 normal $Ba(OH)_2$ was introduced onto the outlet air line, and the carbon dioxide respired per kilogram of fruit per hour was determined. Some of the results are presented in Table 7.

TABLE 7.—RESPIRATION OF PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	When picked	Respiration rate, cc. carbon dioxide per kg. hr.								
		After holding in packing house for			After holding in 32° storage for			After holding in packing house and 32° F. storage for		
		1 day	2 days	3 days	4 days	15 days	25 days	4 days	15 days	25 days
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc
Mature										
Rochester	14.1	29.3	34.5		4.6	4.0	3.8	4.4	4.4	4.3
Vedette	22.8	40.7	32.7		3.7	3.7	3.5	5.1	5.1	4.8
J. H. Hale	10.8	47.3	16.9		3.2	3.4	3.4	3.6	3.4	3.5
Immature										
Rochester	14.5	30.7	34.5		4.5	4.0	3.8	4.4	4.4	4.3
Vedette	19.4	35.3	30.0	35.0	3.7	3.7	3.5	5.5	5.3	5.5

The data presented in Table 7 indicate clearly that the respiration rate of peaches held at packing house temperatures rose rapidly for a day or two after picking. This rapid rise in respiration rate was probably the climacteric in metabolic activity, but may have been stimulated by the wound injury caused by picking the fruit.

With fruit which was stored at 32° F. immediately after picking, respiration rate was not determined until 4 days after the peaches were placed under refrigeration. By that time respiration had fallen to a low rate which was maintained throughout the storage period. The delayed cold storage lots, once they were chilled to 32° F., respired at practically the same rate as similar fruit which was stored immediately. Only in the case of Vedette was there evidence of a slightly higher respiration rate maintained after delayed cold storage fruit was placed at 32° F. The respiration rate of roughly 4 cc. CO_2 per kg. hr. at 32° F. was in sharp contrast to respiration rates ranging up to 47 cc. for peaches held at 70 to 80° F. The respiration trend of immature fruit closely paralleled that of the mature, except that with Vedette not quite so great a respiration intensity was attained.

Influence of Controlled Atmosphere Storage on the Life of Peaches

To secure information concerning the influence of controlled atmosphere (gas) storage on peaches an experiment was conducted in 1941 with fruit of the Rochester and J. H. Hale varieties.

The fruit was enclosed directly in sealed 4-gallon friction-top cans equipped with a gas sampling outlet and punched with a few small holes for the purpose of restricting ventilation of the atmosphere within the can

so as to allow only sufficient exchange of air between inside and outside to prevent the carbon dioxide content within the can exceeding desired limits. Three CO_2 concentrations, 5, 7, and 9% were used with Rochester and two CO_2 concentrations, 7 and 9%, with J. H. Hale. The peaches were held under these concentrations at 32° F. from time of picking until removal from cold storage. Carbon dioxide concentrations maintained in the fruit containers were subject to fluctuations of 1%, and were adjusted every day or two days following analysis of a gas sample by means of an Orsat analyser. The 2 lots of Rochester were removed from cold storage to a 65° F. ripening room after 25 and 41 days respectively, and the J. H. Hale after 27 days.

With the Rochester variety, after 25 days cold storage in all 3 atmospheres, firmness, length of life, and flavour were not significantly improved over fruit stored in ordinary air for the same period, and at the same temperature. In one respect the fruit was seriously harmed by the carbon dioxide atmospheres, for a large proportion of the peaches showed black injured areas on the skin, $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in diameter. This disorder was progressively worse the greater the percentage of carbon dioxide.

At the second removal of Rochester from 32° F. after 41 days' storage, all lots including the checks were mealy and showed incipient breakdown. There was no increase in the black spotting of the skin but rots had developed in many of the affected areas. These results suggest that with the Rochester variety as grown under Okanagan conditions carbon dioxide storage has no value either as a means of delaying development of mealiness or for prolonging life of the peaches after removal from cold storage.

With the J. H. Hale variety, results were equally disappointing. Controlled atmospheres failed to prevent development of a mealy type of breakdown during a 27-day storage period although the breakdown was worse in the check than in the two treated samples.

DISCUSSION

These experiments indicate that the handling of peaches is a matter which requires very close attention to detail if satisfactory results are to be secured. In the first place full maturity of fruit is essential to the development of a well-flavoured product. Less mature fruit keeps somewhat longer and will soften and become ripe, but is bitter and astringent to taste. Peaches mature so rapidly and in such a short period of time in most years that cold storage often becomes necessary to tide over temporary oversupplies of this commodity and to insure orderly marketing. It is during the period of cold storage at the shipping point, refrigerated transport to market, and storage at the market centres that injury to the keeping life of peaches is most likely to occur.

Peaches handled under the best of conditions show a tendency to develop low temperature breakdown after even comparatively short periods of cold storage. Under conditions of these experiments, the safe cold storage period at 32° F. for mid-season varieties was only 3 weeks, and for the later varieties, J. H. Hale and Elberta, only about 1 week. When held in cold storage for longer periods, there was danger of breakdown in the flesh after the fruit was removed to ripening temperatures.

These findings are substantially in accord with those of Harding and Haller (11) and Willison (15). However, Harding and Haller (11) working in the more southern climate of Virginia found that Hale and Elberta could safely be cold stored at 32° F. for 3 to 4 weeks. The warmer temperatures prevailing in Virginia during the harvesting period probably account in large measure for this difference.

The favourable response of peaches to delayed as contrasted with immediate cold storage seems to be due to the fact that the fruit starts its ripening processes and becomes partially ripened before it is placed at 32° F. Partially ripened fruit is capable of completing its ripening when removed from cold storage after a longer period of refrigeration than fruit cold stored immediately without a period of delay at warm temperatures. Apparently, prolonged periods of refrigeration inactivate the enzyme system of peaches so that they lose their capacity to ripen normally, with the result that the fruit remains hard and then develops internal breakdown. With late maturing varieties such as J. H. Hale and Elberta the cold storage period necessary to inactivate the enzyme system is apparently much shorter than with varieties maturing in mid-season such as Rochester and Vedette. For this reason cold storage of J. H. Hales and Elbertas is not recommended, but rather a common storage temperature of about 55° F.

From a practical standpoint most peaches are held at high temperatures for about a day during the period elapsing between picking and packing, and some pre-ripening of the fruit thus takes place. However, to minimize bruising, peaches which are to receive delayed storage treatment should be packed as soon as received from the orchard, and then allowed to stand in the packing house long enough to achieve the desired degree of pre-ripening.

The results from delayed storage experiments reported in this paper are substantially in agreement with those obtained by Davies *et al.* (4, 5, 6) in South Africa. However, these investigators obtained a more complete control of breakdown than was secured in the present experiments. This may have been due to the varieties of white flesh peaches grown in South Africa which differ from the yellow flesh kinds used for these experiments, and also to the length of pre-ripening given the fruit before storage. Davies *et al.* pre-ripened their fruit to a firmness, in some instances, of 4 lb. as measured with the $\frac{7}{16}$ pressure tester point, which is practically eating ripe, and too soft for commercial handling under British Columbia conditions.

The softening of peaches during storage at 32° indicated that even at low temperatures varieties such as Rochester and Vedette undergo considerable ripening, and are thus less able to stand handling the longer they are held in cold storage. In this connection soluble pectin and respiration determinations which measure the physiological basis for softening of fruit, indicated a steady process of ripening even in 32° F. storage.

While satisfactory results have been reported by several investigators (2, 3, 12) with the use of carbon dioxide atmospheres for lengthening storage life of peaches, experiments with Okanagan grown Rochester and J. H. Hale did not indicate any advantage from this procedure. In fact with the Rochester variety storage in atmospheres containing carbon dioxide induced development of skin injury.

SUMMARY

Harvesting and storage experiments designed to provide information regarding the influence of maturity and delayed cold storage on development of low temperature breakdown in peaches are described and the results presented. Seven varieties were used and the work extended over a 2-year period. Pressure tests were taken of the fruit at picking, and during and after the delayed storage period. Skin and flesh colour and soluble solids content of the juice were determined at harvest. At weekly intervals up to 6 weeks after picking, samples of peaches were removed from cold storage to a 65° F. ripening room for observation. Notes were made on condition, eating qualities, and length of life. Chemical determinations of respiration intensity, and formation of soluble pectin during ripening were carried out. A further experiment dealt with influence of carbon dioxide on the storage life of Rochester and J. H. Hale. The more important findings may be briefly stated.

1. Shades of skin colour and flesh colour of mature and immature peaches were determined according to Ridgway's Colour Chart. These colours varied slightly in the two seasons for given varieties. Such colours as amber yellow, barium yellow, Naples yellow, straw yellow and reed yellow, were characteristic of mature peaches. There was a close similarity between skin colour and flesh colour in any given variety.

2. Mature peaches in ideal shipping condition showed a firmness of 14 to 18 lb. with a $\frac{5}{16}$-inch pressure tester point and 20 to 25 lb. with a $\frac{7}{16}$-inch point.

3. Differences in soluble solids content of mature and immature peaches were too small to make this test of value as a maturity index.

4. When picked in the mature condition suitable for fresh shipment and held at 65° F. peaches remained in good condition for the following number of days: Golden Jubilee 8, Rochester 11, Vedette 12, Valiant 13, Veteran 13, J. H. Hale 33, Elberta 26.

5. Picking in a slightly less mature condition lengthened the life of each variety by a few days but only at the expense of quality.

6. When stored at 32° F. immediately after picking, all varieties except Elberta remained free of breakdown for 2 to 3 weeks in 1940, while Elberta held good for only 1 week. In 1941, J. H. Hale and Elberta remained in good condition for only 1 week when stored immediately at 32° F., while Vedette and Rochester stored satisfactorily for 3 and 4 weeks respectively.

7. Softening of the fruit after picking to a firmness of about 10 lb. as measured with the $\frac{7}{16}$-inch pressure tester point appeared to be the optimum amount of pre-ripening necessary to produce a substantial increase in breakdown-free storage life of peaches without rendering the fruit too soft for commercial handling.

8. With the Golden Jubilee, Rochester, Vedette and Valiant varieties a pre-ripening period of 1 day for mature and 2 days for immature samples prior to cold storage resulted in an increase of from 1 to 2 weeks in the breakdown-free life of the fruit.

9. With Hale and Elberta, which required a longer pre-ripening period prior to cold storage, a delay of from 2 to 5 days was necessary to prolong the breakdown-free life for a week.

10. J. H. Hale and Elberta held at prevailing packing house temperatures of about 65° F. kept in good condition as long as similar fruit receiving delayed cold storage treatment, and longer than fruit placed immediately in cold storage.

11. Pre-ripening did not appreciably reduce the life of peaches after removal from cold storage as compared with fruit cold-stored immediately after picking.

12. Delayed cold storage pre-ripening treatment reduced astringency, and improved texture and quality of peaches.

13. In 32° F. storage, Rochester and Vedette peaches softened gradually. Most lots of pre-ripened Rochester and Vedette, at the end of their safe cold storage period, had softened to one-half their degree of firmness when placed in cold storage. Hale and Elberta softened less rapidly.

14. In the processes of ripening at packing house temperatures, there was a very rapid rate of hydrolysis of protopectin to soluble pectin, closely correlated with rate of softening of the fruit. A temperature of 32° F. greatly retarded the rate of soluble pectin formation.

15. Respiration intensity of peaches held at packing house temperatures (60 to 80° F.) rose very rapidly reaching its peak about a day after picking.

16. Respiration rates of approximately 4 cc. CO_2 per kilogram of fruit per hour at 32° F. were in sharp contrast to respiration rates ranging up to 47 cc. for peaches held at 60 to 80° F.

17. Delayed cold storage peaches, once they were chilled to 32° F. respired at a similar rate to peaches stored immediately at 32° F.

18. Immature and mature peaches respired at similar rates.

19. Storage of Rochester and J. H. Hale peaches in atmospheres containing 7 and 9% of carbon dioxide at 32° F. did not lengthen storage life, and in the case of Rochester resulted in skin injury.

ACKNOWLEDGMENT

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RATES OF GROWTH OF BACON-TYPE NURSING PIGS

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Animal growth data have numerous uses, not the least of which is that of serving as standards against which to gauge the results of management and feeding practice. There exists, however, a dearth of published data relative to growth of nursing pigs from which growth curves might be constructed. Ittner and Hughes (2), and Russel (3) have published curves for the growth of nursing pigs, curves which do not differ significantly from each other. Their data are based on lard type hogs where average litter size as well as nursing capacity of the sow may differ markedly from that of the bacon hog produced in Canada. No data appear to have been published for bacon type pigs.

Arrangements were made in 1940 to record weekly live weights of the nursing pigs in the swine herd at Macdonald College. Data suitable for the preparation of growth curves were then obtained from some 140 nursing pigs.

SOURCE AND NATURE OF THE DATA

The pigs used in this study were Yorkshires of Macdonald College breeding. They were the progeny of two different boars mated with sows related to one another as mother and daughter, full-sisters or half-sisters. One-half of the litters were farrowed in January and the other half in May. The male pigs were castrated at 4 weeks of age; and all pigs were weaned between the ages of 56 and 58 days.

The management and feeding of the sows was that generally practised at Macdonald College. The sows' feed consisted of barley, or barley 2 parts and wheat screenings 1 part, plus a protein-mineral supplement. No milk was fed at any time. During pregnancy the meal mixture consisted of 90 parts basal feeds and 10 parts protein-mineral supplement. It was changed to 85 parts basal feeds and 15 parts supplement following parturition. This gave rations of approximately 12 and 17% total protein respectively. The protein-mineral supplement was made up of meat meal, fish meal, linseed oilmeal, bone char, limestone, salt, iron and iodine. Sufficient cod liver oil was fed throughout the pregnancy and nursing periods to supply daily approximately 30,000 and 6,000 I.U. of vitamins A and D respectively.

Creep feeding of the young pigs was not practised, but the lactating sows were full fed 3 times a day to give the young pigs an opportunity to steal some of the feed from the trough.

The pigs were weighed at birth before being allowed to nurse, and each Tuesday thereafter until weaned. Thus the age of the pigs on any weigh day ranged from 3 days younger to 3 days older than the mean age of the group. No weights were taken between birth and the third day.

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PREPARATION OF THE GROWTH CURVE

In the construction of the growth curve (Figure 1) the individual weights recorded were collected into weekly age groups with the 7th, 14th, 21st, etc., days as the mid-points. Thus for example all weights of pigs between 10 and 17 days of age were put into the 14-day group. It may be mentioned at this point that no sex differences were found in any of these data when analysed by Fisher's (1) method of testing for significance of differences. Accordingly, the mean live weights for all pigs in each age group, irrespective of sex, were plotted against age, the curve being smoothed by fitting a second degree polynomial to the weight data. (Fisher's Summation Method (1).)

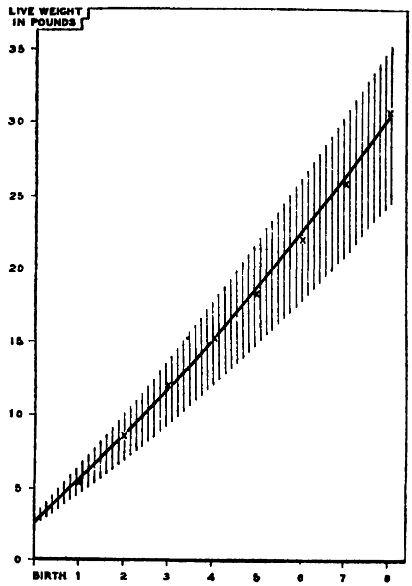

FIGURE 1. Live weights of Yorkshire pigs from birth to 8 weeks of age. Shaded area marks limits of ± one standard deviation about the mean.

RATE OF GAIN IN LIVE WEIGHT

In considering rate of gain as distinct from live weight attained at some specific age, two grouping systems may be employed for the data. The one, rate of gain at a given age, indicates the effects of increasing maturity on the growth of the animal. The other grouping, rate of gain at a given live weight, is often especially useful when feed efficiency is under consideration.

A grouping of the daily gains according to age is given in Appendix Table 2. Graphically, they are shown in Figure 2.

In arranging the data for this curve, the rate of gain for each pig was calculated as the average daily live weight increase between adjacent weighings. The values thus obtained were then applied to the age mid-way between the same two weighings.

The plotting data were smoothed by a third degree polynomial.

In grouping the gains according to attained live weight, the values for daily gain calculated for the gain-by-age curve were now applied to the weight midway between adjacent weighings instead of to the mid-age

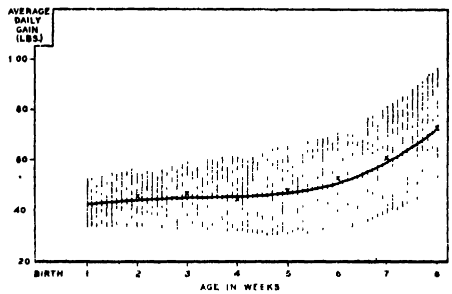

FIGURE 2. Average daily gain of Yorkshire pigs from birth to 8 weeks old according to age. Shaded area marks limits of ± one standard deviation about the mean.

between these points. Plotting points above 33 pounds were not used because the number of observations were deemed too few to have any significance.

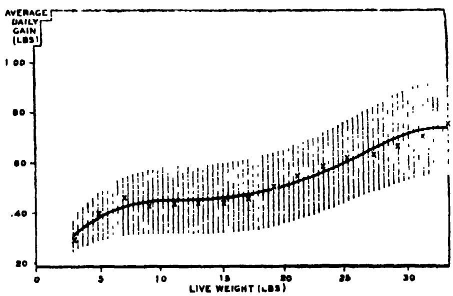

FIGURE 3. Average daily gain of Yorkshire pigs from birth to 8 weeks of age according to weight. Shaded area marks limits of ± one standard deviation about the mean.

The data are given in Appendix Table 3 and the curve, smoothed by fitting fourth degree polynomials, is shown as Figure 3.

SUMMARY

Data are presented of growth of Yorkshire pigs from birth to 8 weeks of age.

Three curves have been constructed as indices of normal growth rates of nursing Yorkshire pigs:

1. Live weight at specific age(s).
2. Rate of gain at specific age(s).
3. Rate of gain at specific weight(s).

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APPENDIX

APPENDIX TABLE 1.—AVERAGE LIVE WEIGHT OF YORKSHIRE PIGS FROM BIRTH TO 8 WEEKS OF AGE

Age of pigs (weeks)	Average live weight (lb.)	
	Observed values	Polynomial values
Birth	2.7 ± 0.4	2.7 ± 0.4
1	5.3 ± 1.4	5.5 ± 1.1
2	8.5 ± 1.8	8.4 ± 1.8
3	11.9 ± 2.3	11.6 ± 2.4
4	15.1 ± 2.9	14.9 ± 3.1
5	18.3 ± 3.7	18.4 ± 3.8
6	21.9 ± 4.5	22.2 ± 4.4
7	25.8 ± 4.9	26.1 ± 5.1
8	30.5 ± 6.1	30.2 ± 5.8

APPENDIX TABLE 2.—AVERAGE DAILY GAIN OF YORKSHIRE NURSING PIGS

Weeks	Age range (day)	Average daily gains (lb.)	
		Observed values	Polynomial values
1	4 - 10	0.42 ± 0.11	0.43 ± 0.10
2	11 - 17	0.46 ± 0.12	0.45 ± 0.12
3	18 - 24	0.47 ± 0.13	0.46 ± 0.14
4	25 - 31	0.45 ± 0.17	0.47 ± 0.16
5	32 - 38	0.48 ± 0.16	0.48 ± 0.18
6	39 - 45	0.53 ± 0.19	0.52 ± 0.20
7	46 - 52	0.61 ± 0.21	0.60 ± 0.22
8*	53 - 59	0.73 ± 0.29	0.73 ± 0.24

* Incomplete as most pigs were weaned on 56th day. Rate of gain for 8th week calculated only for 90 pigs which remained at least 5 days in this period.

APPENDIX TABLE 3.—AVERAGE DAILY GAINS OF YORKSHIRE PIGS FROM BIRTH TO 8 WEEKS OF AGE ACCORDING TO WEIGHT

Weight classes (lb.)	Average daily gain (lb.)	
	Observed values	Polynomial values
3	0.30 ± 0.07	0.32 ± 0.07
5	0.41 ± 0.11	0.39 ± 0.10
7	0.47 ± 0.09	0.43 ± 0.12
9	0.44 ± 0.14	0.45 ± 0.13
11	0.45 ± 0.14	0.46 ± 0.14
13	0.45 ± 0.15	0.46 ± 0.14
15	0.45 ± 0.15	0.47 ± 0.14
17	0.47 ± 0.15	0.48 ± 0.15
19	0.51 ± 0.15	0.50 ± 0.15
21	0.56 ± 0.14	0.54 ± 0.15
23	0.60 ± 0.15	0.57 ± 0.16
25	0.63 ± 0.16	0.62 ± 0.16
27	0.65 ± 0.18	0.66 ± 0.17
29	0.68 ± 0.18	0.71 ± 0.18
31	0.72 ± 0.18	0.73 ± 0.18
33	0.76 ± 0.18	0.74 ± 0.18

DISTRIBUTION OF *FLAVOBACTERIUM MALOLORIS*[1]

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[Received for publication June 8, 1943]

Flavobacterium maloloris was recently described and named by Wolochow *et al.* (3) who isolated 5 cultures of the organism from the water supply of an Alberta creamery. They showed that the bacterium is a causal agent of surface taint in butter, and expressed the opinion that it probably occurs so infrequently in creamery waters as to constitute only a minor factor in commercial surface taint.

The same authors identified as *F. maloloris* 2 cultures supplied to them by Dr. B. W. Hammer, Ames, Iowa, who encountered the organism infrequently in Iowa studies of putrid butter.

The purpose of the present study was to determine the distribution of this species in Alberta waters.

METHODS

The waters were plated on tryptone-glucose-extract-2% skimmilk agar and on nutrient gelatine. The gelatine plates were incubated at 10° C. to 15° C., while room temperature was used for the incubation of the agar plates. After incubation, varying from 3 to 5 days, yellow colonies were fished onto nutrient agar slants. For the determination of Duclaux constants the apparatus and technique of Dunkley (1) and Dunkley *et al.* (2) were employed.

RESULTS

One-hundred-and-forty waters from sources as set forth in Table 1 were obtained from the Provincial Laboratory and the Provincial Dairy Analyst. These yielded 561 cultures of yellow bacteria while 28 additional

TABLE 1.—SOURCES OF WATER SAMPLES

Source	Number of samples
Cities	20
Towns	54
Lakes and rivers	25
War Service Training Centres	16
Unknown	25

cultures were received from students in courses in Dairy Bacteriology. Of these 589 cultures, 239 were gram-negative rods and 11 were gram-variable rods.

[1] These data are taken from a thesis submitted by the senior author to the University of Alberta in partial fulfilment of the requirements for the degree of Master of Science.
[2] Graduate student, Department of Dairying.
[3] Professor of Dairying.

Of the 250 cultures of gram-negative and gram-variable rods, only 23 peptonized litmus milk in the manner characteristic of *F. maloloris* as described by Wolochow *et al.* Each of 21 of these 23 cultures differed from *F. maloloris* by at least two important characteristics (Table 2) and none of the 21 cultures produced the sweaty feet odour in litmus milk.

TABLE 2.—DIFFERENTIATION OF 21 PROTEOLYTIC CULTURES AND *F. Maloloris*

Culture	Growth on T.G.E.M. agar	Motility	Nitrate reduction	Gelatine liquefaction	Indole production	Citrate carbon utilization	Starch hydrolysis	Methyl red test	Voges Proskauer reaction
F. maloloris		–	–	+	+	–	+	–	–
4	S	+	–	+	–	–	–	+	+
36	S	+	+	+	–	–	+	–	–
83a	D	–	+	+	–	+	+	+	–
93a	D	+	–	+	–	+	–	–	–
96, 96a	D	+	+	+	–	–	+	–	–
111a	D	+	–	–	–	+	+	+	–
109, 190a, 192a	S	–	+	+	–	–	+	–	–
197a	S	–	+	–	–	–	–	–	–
199	D	–	–	+	–	+	–	–	–
244	D	–	+	+	+	+	+	–	–
194, 207a, 227	D	+	–	+	–	–	+	+	–
58	D	+	+	+	+	+	–	–	–
19, 136, 217	S	–	–	+	–	+	+	+	–
146	S	+	–	+	–	+	+	–	–

S = Similar.
D = Dissimilar.

Two of the 23 cultures conformed in all respects to the original description of *F. maloloris* and, moreover, they produced the sweaty feet odour in litmus milk and surface taint in butter churned from high-temperature pasteurized, inoculated cream. One culture was isolated from a well water while the other was from a water of unknown source.

Some Further Characteristics of F. maloloris

Wolochow *et al.* found no definite utilization by *F. maloloris* of glucose, sucrose, lactose, or maltose as measured by colour changes in pH indicators. This list of carbohydrates may now be extended to include galactose, mannose, rhamnose, arabinose, xylose, raffinose, mannite and dextrin. The organism did not grow in Koser's citrate medium and lipolysis could not be demonstrated. Duclaux constants indicated the presence of acetic, butyric and isovaleric acids in "steam-distillate residues" from skimmilk cultures of the organism. These are the same volatile acids recognized by Dunkley *et al.* in "steam-distillate residues" from skimmilk cultures of *Pseudomonas putrefaciens*.

DISCUSSION

Since ability to produce yellow growth on common laboratory media was the criterion for isolation and subsequent recognition of *F. maloloris*, it may be that non-pigmented strains were missed. However, in the 9 cultures of the organism which have been studied in this laboratory, chromo-

genesis has been markedly persistent. Non-pigmented growth of any of these strains has not been observed on any solid medium. The criterion of isolation used by Wolochow *et al.* was not pigment but odour production in litmus milk. By these two methods only 7 strains from 3 water supplies have been encountered. If *F. maloloris* occurs frequently in Alberta waters, it appears necessary to assume the existence of strains which are non-pigmented and do not produce the typical odour in litmus milk. Inasmuch as the organism has been encountered and recognized so infrequently in both Alberta and Iowa, there appears to be justification for the opinion expressed by Wolochow *et al.* that *F. maloloris* is less important than *P. putrefaciens* in commercial surface taint in Alberta.

SUMMARY

Only 2 cultures of *F. maloloris* were encountered among 589 isolations of yellow bacteria from 140 Alberta waters. This supports the view that this organism is less important than *P. putrefaciens* as a cause of commercial surface taint in Alberta.

Duclaux constants of steam-distillate residues of skimmilk cultures of *F. maloloris* indicated the same volatile acids as previously reported for *P. putrefaciens*, i.e., acetic, butyric, and isovaleric acids.

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THE EFFECT OF ALKALI WATER ON BONE STRENGTH IN RATS[1]

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In many sections of the Prairie Provinces the water for live stock comes from wells and is alkaline in nature. The long continued use of water high in glauber and epsom salts has often been suspected of having injurious effects on live stock though experimental evidence has been lacking. This paper presents the results of experiments in which rats were used to determine the effects of "representative" alkali waters on bone strength.

MATERIAL AND METHODS

Analyses of well water samples have shown considerable variation but the majority of high alkali samples were very similar in composition. The salts most commonly present were sodium sulphate or glauber salts (Na_2SO_4), magnesium sulphate or epsom salts ($MgSO_4$), calcium sulphate or gypsum ($CaSO_4$). sodium bicarbonate ($NaHCO_3$), and sodium chloride or common salt ($NaCl$).

Saskatoon tap water, which has a negligible content of solids, was chosen as the control treatment. Two other treatments were made up by dissolving sufficient salts in tap water to simulate representative samples from Saskatchewan wells. "Medium" alkali water with a total solid content of 0.75% was produced by adding 0.55% Na_2SO_4, 0.13% $MgSO_4$ and 0.07% $NaHCO_3$. The water designated as "strong" alkali was made up to 1.4% total solids by adding 1% Na^2SO_4, 0.25% $MgSO_4$ and 0.15% $NaHCO_3$.

A breeding colony of albino rats of unknown history was maintained for the purpose of producing experimental animals. In the experiment only 3 animals of one sex or 3 of each sex were used from any one litter. At weaning time these were distributed between the treatments. Group I received tap water, Group II medium alkali water, and Group III strong alkali water.

All of the animals received a standard ration made up as follows:

Ground wheat	30 lb.
Ground barley	20
Ground corn	20
Meat meal	10
Bone meal	4
Skim milk powder	8
Fish meal	5
Brewer's yeast	2
Common salt	.5
Cod liver oil	.5
Total	100 lb.

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[2] Professor of Animal Husbandry.
[3] Instructor in Animal Husbandry.
[4] Instructor in Animal Husbandry.

Bone strength was determined by means of a simple device consisting of two pieces of $\frac{7}{8}'' \times \frac{1}{8}''$ strap iron. One piece 8″ in length was bent in the shape of a clevis, the free ends being just far enough apart to allow the second piece to slide freely. A $\frac{5}{16}''$ hole was drilled through both arms of the clevis about one inch from the ends. A similar hole was drilled near one end of the sliding piece.

The clevis end of the instrument was clamped to a table and the sliding part to a beam scale. To determine bone strength the femur was inserted through the holes and weight applied to the scale until breaking occurred. Both femurs were used for each rat and the breaking weights averaged. The 2 femurs from a single rat usually broke at the same weight and in no case was there a wide variation.

Total ash was determined by placing the entire bodies, without loss of blood or other tissue, in electric furnaces at 700° C. until a constant temperature was achieved. This required approximately 9 hours. Like sex litter mates, 1 from each of the 3 treatment groups were cremated simultaneously.

RESULTS

Bone Breaking Tests

There was no significant difference between the control and medium alkali treatments as shown in Table 1.

TABLE 1.—THE EFFECT OF ALKALI WATER ON BONE STRENGTH IN RATS

	No. of animals		Av. age in days		Av. bone break in lb.		
	Male	Female	Male	Female	Male	Female	Male and Female
Group I Control	9	6	101.3	100.5	36.1	30.4	33.8
Group II Medium Alkali	9	6	101.3	100.5	35.8	31.0	33.9
Group III Strong Alkali	9	6	101.3	100.5	30.9	27.9	29.7
	27	18					32.5

The difference between medium and strong alkali treatments was statistically significant as indicated by the following analysis of variance (Table 2) It is also apparent that the significant difference between sexes was independent of treatment. The larger size of the femurs of males is believed to be largely responsible for their greater strength.

TABLE 2.—ANALYSIS OF VARIANCE OF BONE BREAKING WEIGHTS FOR RATS

Source of variation	D.F.	Sum of squares	Mean square
Between treatments	2	173.6	86.80*
Between sexes	1	218.7	218.70*
Treatment × sex	2	13.9	6.95
Within subclasses	39	755.3	19.37
Total	44	1,161.5	

* Significant at the 1% level.

Total Ash

No significant differences between groups in total ash content was found as indicated in Table 3.

TABLE 3.—THE EFFECT OF ALKALI WATER ON TOTAL ASH CONTENT OF RATS

	No. of animals		Av. age in days		Av. ash content in per cent		
	Male	Female	Male	Female	Male	Female	Male and Female
Group I Control	9	6	101.3	100.5	3.44	3.94	3.62
Group II Medium alkali	9	6	101.3	100.5	3.34	3.95	3.57
Group III Strong alkali	9	6	101.3	100.5	3.38	3.85	3.56

Other Factors

Although this paper is primarily concerned with the effect of alkali water on bone strength in rats some additional data of a preliminary nature were gathered. The rate of growth of the rats was determined by weekly individual weighings from weaning time until the rats were killed and the results are summarized in the following table. It was observed that the rats on alkali water made the poorest gains just after weaning at which time they were least tolerant to the purging effect of the salts.

TABLE 4.—THE EFFECT OF ALKALI WATER ON WEIGHTS AND RATES OF GAIN

	No. of animals		Av. wt at 100 days		Av. daily gain		
	Male	Female	Male	Female	Male	Female	Male and Female
			Gm.	Gm.	Gm.	Gm.	Gm.
Group I Control	8	6	220	156	2.2	1.5	1 9
Group II Medium alkali	8	5	200	154	2.0	1.5	1.82
Group III Strong alkali	7	6	186	145	1.8	1.4	1.67

During the latter part of the experiment the breeding pens were placed on the 3 treatments and the subsequent breeding performance suggested a detrimental effect of alkali water on fertility.

		No. of females	Litters born
Group I	Control	11	24
Group II	Medium Alkali	11	21
Group III	Strong Alkali	11	12

The presence of infection in the colony at a late stage in the trial resulted in a high degree of sterility and thus introduced a new variable.

Histological examination of the thyroid glands of rats from the 3 groups failed to indicate any abnormality. This would indicate that lack of vitamin E absorption was not responsible for the lowered fertility since lack of vitamin E causes a definite hypoactivity of the thyroid.

DISCUSSION

The results of the present investigation indicate that alkali salts must be regarded as a nutritional handicap. This suggests a problem which has assumed considerable importance in the Prairie Provinces. Feeders in some instances have been persuaded to use a crystalline salt product recovered from prairie lakes and sloughs instead of common salt in rationing live stock. This product represents the crystallized form of certain salts present in the water and in most cases the range of salts and their proportions are very similar to those found in the majority of wells. In any case glauber salts predominate and common salt is only present in very small amounts. Glauber and epsom salts, as stockmen know, have certain medicinal properties and can be administered as cathartics, but they will not take the place of common salt in practical live stock rations in this country.

SUMMARY

Bone strength in rats on salt free, medium alkali, and strong alkali waters was determined by means of a shear test. Significant differences between treatments were found indicating that alkali water has a harmful effect on bone development. There was no significant difference between groups in total ash content of the bodies. Rats on alkali water made slower gains than the control group and fertility was impaired.

ACKNOWLEDGMENTS

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BOOK REVIEWS

THE DIAGNOSIS OF MINERAL DEFICIENCIES IN PLANTS BY VISUAL SYMPTOMS. A colour atlas and guide. By T. Wallace. Published by His Majesty's Stationery Office, London. Price 10s.

This book has been written primarily for the use of technical officers and advisers in the British Isles concerned with problems of crop production. It has also been made readable for progressive farmers, vegetable growers, and fruit growers. It is not as elaborate a publication as *Hunger Signs in Crops* because it has been produced in Britain under wartime conditions. However, it contains 52 pages of text on essential points in the nutrition of plants, soils in relation to the supply of mineral nutrients, methods of determining mineral deficiencies in crops, and visual symptoms of deficiencies in crops, together with a chapter on the use of the visual method of diagnosis in the field. The remaining 60 pages of the book include 114 colour plates from colour photographs, running 2 plates to the page with descriptive titles.

The following number of plates appear for the various mineral deficiencies: phosphorus 13, calcium 4, magnesium 22, potassium 23, iron 7, manganese 17, boron 16, together with 6 plates of potatoes in sand culture showing deficiencies in nitrogen, phosphorus, calcium, magnesium and potassium; there are 5 plates showing foliage symptoms which may be confused with nutrient deficiencies including virus yellows in sugar beets, insect injury to cabbage and turnip, and chloride injury to red currant. The plates include mainly deficiency symptoms on potatoes, sugar beets, turnips, cauliflower, kale, tomatoes, beans, mangold, but include also several plates on gooseberries, black currants, raspberries, strawberries, and apples. The plates are not large, averaging about 3″ x 3″. Colour photographs are well taken and in many cases show field backgrounds.

An additional interesting feature of the book is a table of suitable indicator plants. For any one deficiency element a list of indicator plants is given, with the special symptoms which these plants show and references to the plate numbers where these symptoms are illustrated. There is also in tabular form a guide to common symptoms of mineral deficiencies of cereals, Brassica crops, beet crops, potatoes, beans and peas, clovers, carrots and parsnips, tomatoes and fruit crops.

This publication would appear to be a valuable addition to the literature on visual symptoms of mineral deficiencies, and should be very useful to the research workers in connection with the reading of current literature in British publications in which colour plates could not be provided with the individual papers. It will also be of interest to compare the plates in this publication with plates published on this continent.

H. L. T.

THE PRODUCTION OF SEED OF ROOT CROPS AND VEGETABLES. Imperial Agricultural Bureaux Joint Publication No. 5. Available from Imperial Agricultural Bureaux, Central Sales Branch, Agricultural Research Building, Penglais, Aberystwyth, Great Britain. Price 3s.

Among the numerous readjustments that have had to be made since 1939 in agricultural production in countries outside Europe, those concerned with the supply and distribution of seeds of agricultural and horticultural plants demand an important place. Isolation from the former seed producing countries of central Europe and the great risks affecting the transport of consignments of seed across the seas from one country to another have led to the attempt to achieve self-sufficiency in seed supplies in all countries where production is at all possible. This development is probably more marked with respect to seeds of root crops and vegetables than with any other seed. New areas have had to be located which are best suited to this type of production, new techniques have had to be studied and passed on to the cultivators, and attention has had to be given to the choice of adapted varieties and to the distribution and marketing of the final product.

This publication describes these new developments in as many countries as have been accessible under present abnormal conditions. The various articles describe the extension of the production of seed away from the areas where conditions especially favoured this industry to countries less suited in many cases, and in some cases, for example, Scotland, Sweden and Canada, to countries actually on the fringe of the possible seed producing latitudes.

The Canadian contributions to this publication include an article on root crop seed production by T. M. Stevenson and R. M. MacVicar, and vegetable seed production by T. F. Ritchie, of the Central Experimental Farm, Dominion Department of Agriculture, Ottawa. Articles are included from England, Scotland, Netherlands, Sweden, United States of America, Canada, Australia, New Zealand, South Africa, and the Colonial Empire.

SCIENTIFIC AGRICULTURE

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THE LARCH SAWFLY, *PRISTIPHORA ERICHSONII* (HARTIG) IN BRITISH COLUMBIA, WITH SPECIAL REFERENCE TO THE COCOON PARASITES *MESOLEIUS TENTHREDINIS* MORLEY AND *TRITNEPTIS KLUGII* (RATZEBURG)[1]

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HISTORY

The European larch sawfly, *Pristiphora erichsonii* (Hartig), has slowly but steadily spread westward in North America since Hagen (6) discovered it in Massachusetts in 1881. In 1883 Fyles (3) reported its appearance in Eastern Canada; during the next 10 years, most of the mature larches in that region were destroyed by it. The sawfly had become well established as far west as Battleford, Saskatchewan, by 1911 and was also present in the Riding Mountain Forest Reserve of Manitoba. It was found in the north from James Bay eastward to Labrador. It was reported from Michigan and Minnesota in 1909.

P. erichsonii was first noted in British Columbia in 1930, by a forest survey party of the British Columbia Forest Service. In an unpublished report by H. J. Hodgins (9) based for the most part on surveys made in 1930, the following entry occurs on page 13: "The larch sawfly was found in abundance in the immature compartment 33 C, Graves Creek." This creek enters the Elk River about 30 miles north of Fernie.

Unfortunately, this infestation was not drawn to the attention of entomologists, and it was not until the summer of 1933 that we knew of the presence of the sawfly. At that time, through the co-operation of the Provincial Forestry Office at Victoria, larvae collected by F. Woodhouse of Fernie were submitted to the Vernon Forest Insect laboratory. These specimens were taken from western larch (*Larix occidentalis* Nutt.) on the Hartley Wilson estate in the city of Fernie. A survey conducted in September 1933 proved that the sawfly was present in the Elk River Valley for a distance of 35 miles north of Fernie, and at least as far westward as Soda Creek, 10 miles west of Elko.

Since then the sawfly has advanced steadily, following the distribution of western larch which is confined to the main river and lake systems. In 1934 more extensive surveys revealed that it occurred from Columbia Lake on the north, southward to Idaho, and from Corbin on the east to Rosen Lake west of Elko. Subsequent examination of terminals at Lumberton showed that eggs had been laid several years previous to 1934. In 1935 it was seen at Kitchener, and the following year was discovered at Boswell

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on the east shore of Kootenay Lake. In 1937 it was found on the east side of Slocan Lake and it reached the northern end in 1939. In 1940 it was present at Whatshan Lakes just west of Arrow Lakes, and by the following year had spread nearly to the summit of the Monashee range adjacent to the road between Edgewood and Vernon. In 1942 it was collected near Vernon in the Okanagan Valley, which is about the western limit of *Larix occidentalis*. Thus it has taken approximately 60 years to spread across the continent. The accompanying map shows the present known distribution of the sawfly in British Columbia in relation to that of western larch.

OBJECT AND METHODS

This article is presented chiefly to show the relative abundance or scarcity of the hymenopterous parasites *Mesoleius tenthredinis* Morley and *Tritneptis klugii* (Ratzeburg) from 1934, up to and including 1942. It also shows the increase in distribution of the sawfly and gives data on the liberations and recoveries of *M. tenthredinis*. An attempt is made to show, in a general way, the extent of conflict between *M. tenthredinis* and *T. klugii* and to clarify some hitherto obscure points in the life history of the latter species.

Factors such as the fungus *Isaria farinosa* (Dicks) Fr., weather effects, destruction by mammals and other predators, have not been investigated individually to any extent. Since *I. farinosa* is known to be saprophytic and is also supposed to be parasitic, it has not been possible to separate the effect of winter killing from that caused by the fungus. In other words the fungus almost invariably invades cocoons in which the larvae have been killed by freezing.

It is also extremely difficult to evaluate the effectiveness of rodents and other mammals. The rodents' habit of gathering the cocoons into caches disturbs the normal distribution of cocoons and affects the accuracy of sampling. The method of identifying cocoons opened by mammals by the type of hole in the cocoon is open to question. There is also no way of knowing whether such cocoons contained living sawfly stages or parasites, unless it can be shown that there is a definite selection on the part of the mammals with regard to cocoon contents. Selectivity of this nature by shrews, but not by rodents, has been indicated by Morris (10) for the European spruce sawfly.

It should therefore, be clearly understood that in Table 2, showing sawfly parasitism and survival, the mortality indicated in column B was due to the combined effects of weather, *Isaria*, and mammals. It may be presumed that the same percentage of parasitism would apply to these cocoons as to those unmolested by the above agents. Consequently these are subtracted from the total number in the sample for purposes of computing percentage of mortality due to *M. tenthredinis* and *T. klugii*.

Collecting of cocoons was carried on from 1934 to 1942 inclusive, with the exception of the years 1937 and 1938. Until permanent plots were established in 1939, mass samples, usually of several thousand cocoons each, were taken from selected areas in the Fernie district. In these earlier samples, parasite recovery was the main object and therefore in collecting an attempt was made to eliminate cocoons destroyed by mammals or

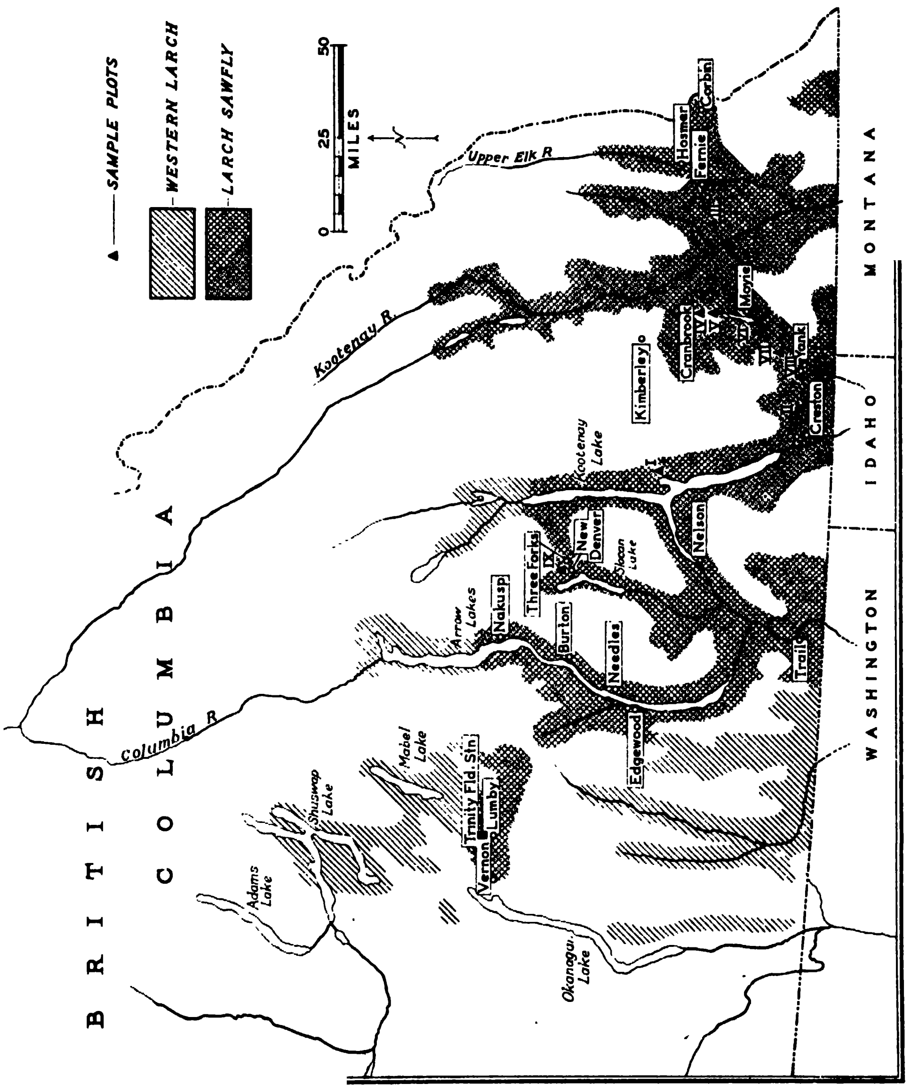

FIGURE 1. Distribution of the larch sawfly.

infected by *Isaria*. Only apparently sound cocoons were taken. Each sample comprised cocoons from beneath 15 to 20 larches ranging in height from 20 to 30 feet. These occurred in scattered, nearly pure stands situated on benches a few hundred feet above the Elk River. The collections were made in the spring before any sawfly emergence had started and the cocoons were placed in cages at a temporary field station (Lizard Creek) near Fernie. Emergence occurred under conditions of air temperature and humidity. The adult sawflies and parasites were removed as they emerged until no more appeared. The remaining cocoons were then examined to determine the contents.

In 1939, nine sample plots were established, located as shown on the accompanying map. These varied from ¼ acre to 1 acre in area, according to the character of the stand. The number of larch trees per plot varied from 35 to 185. Nearly pure stands of larch occupied the plots, the trees ranging in height from 10 to 75 feet and in diameter from 2 to 14 inches. The sampling was carried out in 1940 and 1941 in the spring of the year before any emergence had taken place.

The method used was to take 2 samples, each 1 foot square, beneath every tenth tree on each plot, to a soil depth where no more cocoons could be found. Each sample was taken approximately midway between the trunk of the tree and the point directly beneath the outer edge of the crown. If the first 2 samples were taken on the east and west sides of a tree, respectively, the next 2 were taken on the north and south sides, alternating in this manner throughout the plot. Wooden frames were used to measure the sample area and the edges were cut through with narrow-bladed trowels. Each sample of duff was broken into fine pieces over a square of white canvas. The soil portion of each sample beneath the duff was screened for cocoon recovery. Samples were examined within 2 weeks after collecting.

In this sampling work an attempt was made to identify cocoons opened by mammals as well as to record those infected by *Isaria* and those parasitized by *M. tenthredinis* and *T. klugii*. Mass samples were taken near 1 or 2 of the plots where cocoons were numerous, in an attempt to establish the presence or absence of *M. tenthredinis*. These were handled in much the same way as the Fernie samples.

For the purposes of this article, detailed plot descriptions and sample analyses seem unnecessary and only a summary of results is given in Table 1.

The random samples taken in 1942, on the sample plots and in other localities, were collected in the fall of the year and were examined shortly after collection. These also were chiefly intended to show the numbers of *M. tenthredinis* found by dissection and the numbers of cocoons attacked by *T. klugii*.

Work on the life history of *T. klugii* was carried out under air temperature and humidity conditions in the insectary at Trinity Valley Field Station, 22 miles from Vernon. For mass rearings, jelly jars were used containing 100 cocoons each and covered with fine woven cloth. For individual rearing, large vials were used, stoppered with cotton.

TRITNEPTIS KLUGII (RATZEBURG)

One parasite which has accompanied the sawfly in its westward spread is the chalcid, *Tritneptis klugii* (Ratzeburg). The taxonomy of this species is given by Gahan (4). The biology is well discussed by Hewitt (7, 8) under the name *Coelopisthia nematicida* Packard, and the description and much of the life history need not be repeated. However, one point not determined is the number of generations which may occur in a season. This was investigated in 1941, using single lines of descent. Cocoons used for the first spring emergence were collected near Slocan Lake in the fall of 1940.

Seven lots of 25 parasitized cocoons each were used. The first generation of adults emerged between June 5 and 25 with the peak on June 13. A total of 6,120 *T. klugii* were recovered, giving an average of 35 per cocoon. The highest average for any individual lot was 42.1, the lowest, 26.

For second and third generation rearings, 5 lots of 5 cocoons each were used. Adults of the second generation emerged between July 12 and 25, with the peak between July 13 and 18. A total of 1,648 adults emerged, averaging 65.8 per cocoon. The highest average for a single lot was 82.2, the lowest, 15.

Third generation adults emerged between August 11 and 19 with the peak between August 13 and 16. They numbered 1,127, an average of 45 per cocoon. The highest average per cocoon for any lot was 65.8, the lowest, 15. These chalcids laid eggs in new lots of cocoons but no further emergence of adults took place in 1941. This indicates that it is possible to have 3 generations of *T. klugii* a year in British Columbia. The scarcity of full cocoons between the emergence of adults and the time new cocoons become available probably limits the numbers of second and third generation parasites to some extent. However, new cocoons are present in some years before the peak of sawfly emergence, while pupae in old cocoons are still available. Usually there are also some cocoons containing larvae in diapause. In 5 localities near Fernie in 1935, diapause ranged from 0.64 to 22.2% in the mass samples.

Hewitt (7, 8) estimated that because a summer brood only required about 23 days to develop, it would be possible to have 6 broods between the latter part of May and the beginning of October. In British Columbia, the shortest developmental time required to produce 1 summer generation under air temperature and humidity conditions was 29 days. It is not probable, therefore, that 6 generations could occur here under field conditions. Also, the elapsed time between emergence and the findings of suitable cocoons in which to oviposit would tend to limit the number of broods, especially where the cocoon population is low.

The percentage of males in the above 3 generations varied from 13 to 15. Females can reproduce parthenogenetically, but in such cases all of the progeny are males. These males are, on the average, larger than those produced from cocoons containing both males and females. In confinement females will live 2 weeks without food; males die sooner.

MESOLEIUS TENTHREDINIS MORLEY

The ichneumonid parasite, *Mesoleius tenthredinis* Morley, was first released in British Columbia in July 1934. The specimens were received from the Dominion Parasite Laboratory at Belleville, Ontario, where they had been reared from cocoons collected at Parke Reserve, Quebec. Three lots were received totalling 721 males and 406 females. Of these 393 males and 280 females were alive and active on arrival and were liberated at one point on Lizard Creek, 2 miles from Fernie. Subsequent liberations were made as follows:

		Males	Females
1935	Rosen Lake	100	189
	Hosmer	1,057	626
1936	Lizard Creek	37	56
	Rosen Lake	84	145
	Lumberton	55	50
	Kitchener	182	206
1941	Fire Valley (Edgewood)	331	284
1942	Fire Valley	143	147
	Shuswap River	190	184

Thus a total of 2,572 males and 2,167 females have been liberated. There is some evidence that this parasite was not present in the Fernie region prior to liberations of eastern material. In 1933 the most intensive sawfly infestation was in the immediate vicinity of Fernie. In September of that year 1,600 cocoons were collected on the Wilson estate by W. G. Mathers and overwintered in soil at the Vernon laboratory. Emergence from these cocoons the following spring failed to produce any *Mesoleius* and examination of the remaining cocoons was also negative. On June 8, 1934, H. B. Leech collected 78 cocoons on the Lizard Creek area and shipped them to Belleville, Ontario. On August 13 and 14 of the same year, H. B. Leech and G. R. Hopping collected on the Wilson property and shipped 5,200 cocoons to Belleville. Mr. A. B. Baird reported that examination of emerged and unemerged material failed to to show any *Mesoleius*. On the other hand, Dowden (1) reports the recovery of *M. tenthredinis* and other species of parasites from larch sawfly cocoons collected in 1935 along the north fork of the Flathead River, in northern Montana. This sawfly infestation, which extended into British Columbia, is only about 40 miles in a direct line from Fernie.

CONFLICT BETWEEN M. TENTHREDINIS AND T. KLUGII

At Fernie, in 1935, *M. tenthredinis* was sometimes parasitized by *T. klugii*. Evidence has indicated that this conflict, in some cases, is enough to reduce the effectiveness of *M. tenthredinis* rather seriously, *T. klugii* being able to parasitize larvae, pupae, and even teneral adults of the ichneumonid. The larvae of *T. klugii* complete their growth and emerge successfully, though the number per cocoon is greater when the sawfly is the host.

On the upper Elk River in 1935 *T. klugii* parasitized 59 out of 156 *M. tenthredinis* in a sample of 2,081 cocoons. On the same area in 1936, this hyperparasitism amounted to 36 out of 955. In 1942, on plot VI, *T. klugii* parasitized 9 out of 40 *M. tenthredinis*. These samples represent the highest observed hyperparasitism by *T. klugii*. In view of the fact that *M. tenthredinis* attained a parasitism of 88% at Treesbank, Manitoba, in 1927, where *T. klugii* was apparently absent, it may not be advisable to introduce the latter species into areas containing *M. tenthredinis*. However, it does seem advisable to establish *M. tenthredinis* on areas where *T. klugii* is already present, since the latter alone has not attained a parasitism over 50% in our mass samples, while the 2 parasites together have attained over 70% parasitism in mass samples from several different areas. The general impression obtained from the sample data is that total parasitism of the sawfly cocoons has been increased by the introduction of *M. tenthredinis* into British Columbia.

BESSA SELECTA MEIGEN

The tachinid, *Bessa selecta* Meigen, was already present in the Fernie region in 1934. Of 924 larch sawfly larvae collected that year, 47 had *Bessa* eggs on them, but only 15 adults were reared. The following year an increase was indicated since 94 larvae collected on the same area had 54 *Bessa* eggs on them. Since then this parasite has been relatively scarce.

The flies seem to prefer third and fourth instar larvae on which to oviposit. As many as 6 eggs have been found on 1 larva but the usual number is 1 or 2. Two liberations of *B. selecta* totalling 2,511 males, and 3,189 females were made in 1942, one on July 4 in Fire Valley near Edgewood, and one on July 7 near the Shuswap River, 24 miles east of Vernon.

Two specimens of another tachinid, *Phorocera* sp., have been reared from the larch sawfly in British Columbia, 1 from the upper Elk River and 1 from Corbin.

ZENILLIA NOX HALL

In 1935, 872 adults of a Japanese sawfly parasite, the tachinid *Zenillia nox* Hall, were released, 116 at Rosen Lake and 756 at Hosmer. No field recoveries have been made and it is doubtful that the species became established.

ISARIA FARINOSA AND WEATHER

At Hosmer in the spring of 1936, over 70% of the sawfly cocoons were infected with *Isaria farinosa* (Dicks) Fr., but it was impossible to distinguish those which might have been killed by the fungus from those which had been killed by low temperatures (−2° to −14° F. from October 30 to November 3) of the previous year. The ground at that time had no cover of snow and the mortality in the cocoons must have been high, but the invasion of the cocoons by *Isaria* obscured this effect. However, *Isaria* has been present every year samples were taken. In 1934 the percentage of cocoons affected varied from 1% on dry shallow soil covered by thin duff to 9% on moist sites with thick duff. There is some evidence to show

that *Isaria* is the primary cause of death in at least some instances. In the samples collected in the Fernie district in 1934 the fungus continued to spread to apparently healthy cocoons after collection.

PREDATORS

Predators appear to be less important than parasites in reducing the sawfly population. "Yellow-jackets" (*Vespula* spp.) prey on the caterpillars to a limited extent. The larvae of an elaterid beetle, *Ludius lutescens* Fall, are numerous at times in the duff and several, found partly inside cocoons, were eating the larvae. They had obviously made their own entrance holes.

Only 1 species of bird, *Turdus planesticus propinquus*, the western robin, was observed to eat the sawfly larvae.

Small mammals such as mice and shrews feed quite extensively on larvae in cocoons, particularly during winters with deep snow which remains later than usual in the spring. Large caches of opened cocoons beneath logs and at intervals along the winding tunnels testify to this. Usually the duff has been searched for cocoons for an inch or more on each side of such tunnels.

DEFOLIATION

Defoliation of each tree on the sample plots has been recorded every year since 1939 and supplementary notes have been taken covering the general infestation. Criteria used for judging defoliation were as follows:

Light— No noticeable defoliation; some terminals curled by egg-laying detected after a few moments inspection.

Medium—Upper third of crown noticeably thin. Curls fairly numerous.

Heavy— Half or more of crown practically stripped of needles. Curls numerous.

In 1933 heavy defoliation occurred on rather limited areas from 4 miles northeast of Fernie, westward to Lizard Creek. Other areas showed light to medium defoliation. The following year defoliation was heavy at Lizard Creek, Hosmer, on the upper Elk River, at Corbin and Sand Creek, west of Elko. On all other areas it was light to medium. In 1935 defoliation was very light over the entire area of sawfly distribution. This was unexpected in view of the sawfly survival and the extensive egg-laying noted. Extremely wet weather during hatching and young larval stages may have caused a high mortality before any heavy feeding could occur. Defoliation was again generally light from 1936 to 1938, inclusive. No appreciable defoliation occurred in 1937 and it was difficult to find any cocoons. Egg scars on new shoots were very scarce.

In 1939 defoliation was light from Slocan Lake eastward to the west side of Kootenay Lake. It was medium to heavy from Grey Creek on the east shore of Kootenay Lake eastward to Cranbrook. East of this point it was light to medium. In 1940 areas of heavy defoliation had shifted to

the Slocan Lake region, particularly on Carpenter Creek. Areas from there eastward were generally light. In 1941 defoliation was again medium to heavy around Slocan Lake but light on other areas. In 1942 the centre of heavy defoliation again shited westward to areas more recently invaded by the sawfly. The heavier defoliation occurred along Arrow Lakes and it was medium to heavy in Slocan Valley. It was light to medium in the Nelson district and at Grey Creek. From Creston eastward to the Fernie region defoliation was light.

Five larch trees have died on the sample plots since 1931. These trees were all 6 inches or under in diameter and were obviously suppressed trees. Although defoliation by the larch sawfly may have been the immediate cause of death, the indications were that these trees would have been killed in a few years by shading out.

SUMMARY AND CONCLUSIONS

The parasites *M. tenthredinis* and *T. klugii* are well distributed over the areas infested by the European larch sawfly and they are important control factors. While there is some conflict between the two owing to hyperparasitism of *M. tenthredinis* by *T. klugii*, this does not appear to be serious in most cases. It seems to be advantageous to introduce *M. tenthredinis* into areas where *T. klugii* is already present but the reverse is not recommended until more is known about the inter-relationship of the 2 parasites.

The tachinid, *Bessa selecta* Meigen, is widespread but not so important as the above 2 species. The fungus, *Isaria farinosa* (Dicks) Fr., may be valuable under certain moisture conditions. Predators are less effective than parasites. Weather may have been a control factor in 1935.

In British Columbia the general indication is that defoliation has been heavy during the first few years after the sawfly has become established. After that, zones of heavy defoliation have decreased in number and size. It may be that natural control factors now operating over much of the sawfly area of British Columbia will be able to keep the sawfly population down sufficiently to prevent any lasting damage to the western larch stands.

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TABLE 1.—SAWFLY MORTALITY BASED ON SAMPLE PLOT DATA

Year	Plot no.	No. of samples	A Total no. cocoons examined	B Old cocoons	C A minus B	D Openeed by rodents		E Infested by *Isaria*		F C minus (D + E)	Parasitized by *Tritneptis*		Parasitized by *Mesoleius*		Sawflies surviving	
						no.	%	no.	%		no.	%	no.	%	no.	%
1940	1	11	195	50	145	19	13.1	16	11.0	110	81	73.6	0	0.0	29	20.0
	2	15	13	3	10	7	70.0	0	0.0	3	3	100.0	0	0.0	0	0.0
	3	14	4	0	4	3	75.0	0	0.0	1	1	100.0	0	0.0	0	0.0
	4	15	28	9	19	2	10.5	4	21.1	13	7	53.8	0	0.0	6	31.6
	5	18	53	16	37	19	51.4	13	35.1	5	2	40.0	1	20.0	2	5.4
	6	12	119	36	83	6	7.2	38	45.8	39	30	76.9	0	0.0	9	10.8
	7	12	572	62	510	66	19.4	234	45.9	210	90	42.8	4	1.9	116	22.7
	8	6	95	43	52	18	34.6	13	25.0	21	19	90.5	0	0.0	2	3.8
	9	12	9	0	9	2	22.2	2	22.2	5	1	20.0	0	0.0	4	44.4
	Totals	115	1,088	219	869	142	16.3	320	36.8	407	234	57.5	5	1.2	168	19.3
1941	1	11	233	75	158	50	31.6	55	34.8	53	51	96.2	0	0.0	2	1.3
	2	10	10	3	7	2	28.6	2	28.6	3	3	100.0	0	0.0	0	0.0
	3	14	5	3	2	0	0	0	0.0	2	2	100.0	0	0.0	0	0.0
	4	15	21	5	16	8	50.0	1	6.3	7	4	57.1	0	0.0	3	18.7
	5	18	64	20	44	7	15.9	24	54.5	13	13	100.0	0	0.0	0	0.0
	6	12	125	20	105	15	14.3	44	41.9	46	39	84.8	0	0.0	7	6.7
	7	10	190	22	168	37	22.0	84	50.0	47	35	74.5	0	0.0	12	7.1
	8	LOGGED IN 1940														
	9	12	6	1	5	0	0	240.0		3	1	33.3	0	0.0	2	40.0
	Totals	102	654	149	505	119	2.36	21242.0		174	148	85.1	0	0.0	26	5.1

TABLE 2.—SAWFLY PARASITISM AND SURVIVAL BASED ON RANDOM SAMPLES

Year	Locality	A	B	C	D				E	F	
		Total no. cocoons examined	Mortality from causes other than insect parasites	A minus B	Parasitized by				Dipterous parasites	Sawflies surviving	
					Tritneptis		*Mesoleius*				
					no.	%	no.	%		no.	%
1934	Fernie	455	69	386	76	19.7	0	0.0	—	310	68.1
	Hosmer	132	24	108	44	40.7	0	0.0	—	64	48.4
	Upper Elk R	355	69	247	41	16.6	0	0.0	—	245	69.0
1935	Hosmer	2319	1229	1090	204	18.7	9	0.8	—	877	31.7
	Upper Elk. R.	2081	716	1365	117	8.6	156	11.4	1	1091	52.4
	Corbin	335	154	181	15	8.3	9	5.0	1	156	46.6
	Lizard Cr.	1552	595	957	327	34.5	6	0.6	—	624	40.2
1936	Hosmer	3441	2596	845	185	21.9	352	41.6	—	308	8.9
	Upper Elk R.	3313	1683	1630	274	16.8	955	58.6	—	401	12.1
1940	Moyie Lake	1471	673	798	336	42.1	12	1.5	—	126	15.7
1941	Alamo (Slocan Lake)	2497	548	1949	576	29.5	53	2.7	—	1320	52.8
1942	Plot I	21	0	21	0	0.0	6	28.6	—	15	71.4
	Plot IV	4	0	4	0	0.0	1	25.0	—	3	75.0
	Plot V	50	2	48	3	6.2	13	27.1	—	32	64.0
	Plot VI	150	27	123	49	39.9	40	32.5	—	34	22.6
	Plot VII	50	14	36	17	47.2	14	38.7	—	5	10.0
	4.0 mi. S. Grey Creek	132	10	122	7	5.7	59	48.3	—	76	57.6
	8.9 mi. W. Nelson	86	2	84	37	44.0	0	0.0	—	47	54.6
	26.8 m. W. Nelson (Slocan Valley)	50	10	40	14	35.0	0	0.0	—	26	52.0
	28.1 mi. S.E. Nakusp	43	11	32	12	37.5	16	50.0	—	4	9.3
	10.9 mi. S. Nakusp	50	1	49	0	0.0	3	6.1	—	46	92.0
	1.0 mi. S. Burton	50	3	47	1	2.1	7	15.0	—	39	78.0
	2.5 mi. N. Needles	42	2	40	0	0.0	4	10.0	—	36	85.7
	9.0 mi. W. Edgewood	50	12	38	3	7.9	1	2.6	—	34	68.0
	16.0 mi. W. Edgewood	50	3	47	6	12.7	2	4.3	—	39	78.0
	Trinity Field Station	36	1	35	0	0.0	0	0.0	—	35	9.7

THE IRON CONTENT OF BUTTER AND ITS RELATION TO THE BUTTER WASH WATER[1]

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Considerable attention has of late been given to the iron content of butter (Davies (2), Williams (11), Moir and Andrews (7)).

Milk is reported (5) to contain 0.31 to 0.44 p.p.m. of iron as it leaves the cow and this is considered a deficiency from the human nutritional point of view. On the other hand, cream as received at the creamery for churning purposes often contains considerable amounts of this metal, presumably the result of the contact of the milk and cream on the farm with exposed iron in utensils, such as pails, separators and shipping cans. Although the creameries have made great strides towards the elimination of iron in their equipment, one may still observe vats of tinned galvanized iron for holding cream, rusty churn door frames, bolts, etc. Thus the addition to the cream of iron from creamery equipment cannot be excluded as a possibility.

Not infrequently the creamery receives a shipment of cream containing sufficient iron to lend to it a metallic taste. Such cream is shunned by the buttermaker as he realizes that he has no means of preventing the defect from being carried over into the butter, that the butter will receive a low initial score and that in addition it possesses poor keeping quality.

Aside from metallic butter due to the presence of considerable amounts of iron, the catalytic action of relatively small quantities as a factor in promoting such butter defects as tallowy, oily, fishy, storage flavours and other defects of an oxidative nature is well recognized.

As most of the butter produced in Alberta is made during the summer months, much of it has to be held in cold storage for considerable time. Consequently, any agent such as iron, having a deteriorating effect on the butter under storage conditions becomes of marked significance.

It was with these thoughts in mind that a survey of the iron content of Alberta creamery butter was started. This survey covered 27 creameries and a total of 146 churnings.

ANALYTICAL METHODS

In principle, the thicoyanate method of Thomson (10) was employed.

Twenty-five g. lots of butter, in duplicate, were weighed into glazed sillimanite crucibles that had been boiled in concentrated sulphuric acid and rinsed with distilled water. The crucibles were kept submerged in concentrated sulphuric acid when not in use. If they showed signs of corrosion, they were discarded. The butter was placed in an asbestos-lined electrical oven and the temperature slowly raised to drive off the water.

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The sample was then transferred to an open flame from a nickel plated burner and the temperature raised high enough to ignite the fat. Following the suggestion of Davies (2) the charred mass was extracted with water to dissolve out the salt and filtered. The filter paper and residue were returned to the crucible. After ashing, 2 ml. of concentrated nitric acid and 10 ml. of water were added and the mixture gently boiled for ten minutes to dissolve the ash. When cool, the contents were washed into the beaker holding the salt solution, 1 ml. of a 3% hydrogen peroxide solution added and the mixture allowed to stand 10 minutes. It was then filtered into a 50 ml. Nessler cylinder through a filter paper, which had been washed with 1 N. nitric acid. Five ml. of 5% potassium thiocyanate solution were added to the solution in the cylinder, which was then made up to the mark with water and mixed well. Two ml. of concentrated nitric acid, 1 ml. of 3% hydrogen peroxide and 5 ml. of 5% potassium thiocyanate were similarly added to a matched cylinder partly filled with water. An iron solution (9) diluted to contain 0.025 mg. of iron per ml. was introduced from a burette until the colour of the standard matched that of the sample. The level was adjusted to the 50 ml. mark and the reading was taken. One ml. of the iron solution was equal to 1 p.p.m. of iron, when a 25 g. sample was used.

The analyses were usually run in lots of 6, together with a blank. The reading of the blank remained practically constant at 0.2 p.p.m. and duplicates usually agreed very well.

Although no elaborate technique was evolved for eliminating completely iron in the chemicals and other material used, (for instance the nitric acid contained traces of iron) every effort was made to have conditions of analysis as uniform as possible, and the same lots of chemicals and filter paper (No. 00, 9 cm. Munktell) were used throughout. In addition much care was exercised to prevent contamination with iron during analysis. It was the experience that unless these precautions were taken uniform results could not be expected.

From Table 1 it will be noticed that there is a significant difference in the iron content of butter from different creameries. For instance, 6 first grade churnings from Creamery No. 18 had an average iron content of 0.48 p.p.m., whereas, the 6 first grade churnings from Creamery No. 27 showed an average of 2.37 p.p.m. Furthermore, it will be observed that the tendency for the iron content is to remain rather uniform within the same plant, particularly when dealing with first grade butter.

Generally the second and lower grades within the same plant contained more iron than the first grade butter. However, there were many exceptions and some low grade churnings had a low iron content.

New Zealand workers (7, 8), have placed the upper safe limit for the iron content of storage butter at 1.5 p.p.m. When churnings reported in Table 1 are grouped accordingly, we find for first grade butter out of a total of 123 churnings, 91 or 74% contained less than 1.5 p.p.m. and 32 churnings, or 26% contained 1.5 p.p.m. of iron or over. For second or lower grades, of a total of 23 churnings, 11 churnings, or 48% contained less than 1.5 p.p.m. and 12 churnings, or 52% contained 1.5 p.p.m. of iron or more.

TABLE 1.—THE IRON CONTENT OF 146 CHURNINGS OF ALBERTA CREAMERY BUTTER IN PARTS PER MILLION

Cry. no.	First grade butter	Butter below first grade	Fe content of creamery water p.p.m.
1	0.6, 0.6, 2.0, 0.9, 0.8, 1.2, 1.0	1.4, 1.5, 2.7, 0.8	<0.1
2	0.7, 0.6, 0.6, 0.6		0.6 to 0.8
3	2.5, 1.7, 1.6, 2.6, 2.4, 1.4, 2.4, 1.9	2.5	7.0
4	0.8, 0.7	0.6	<0.1 to 0.1
5	1.4, 0.7	0.7	1.7
6	0.8, 1.6, 1.6, 0.8	0.8, 2.5	0.6
7	0.6, 0.6, 1.2, 0.7, 0.6, 0.5, 0.9, 1.1, 0.6		<0.1 to 0.1
8	0.8	0.6	<0.1
9	1.2, 1.2	1.0	<0.1
10	1.0, 0.8		0.6
11	1.4, 1.4, 1.2, 1.3, 0.6, 0.9	0.7	1.4
12	0.9, 1.3, 1.2, 1.1, 1.0, 1.0	2.6	0.4 to 1.6
13	1.2, 1.8, 1.4		1.0
14	0.6, 0.4, 0.4		0.3
15	1.4, 1.4, 1.4		—
16	1.0, 0.7, 0.6, 0.8		<0.1
17	1.5, 1.4, 1.0, 0.9, 1.1, 1.1, 0.8, 1.0	1.4, 1.1	4.0
18	0.4, 0.6, 0.5, 0.5, 0.5, 0.4		<0.1
19	1.5, 1.4, 1.9, 1.6, 1.7, 1.8, 1.7	2.5, 2.1	3.6
20	0.5, 0.7, 0.4		<0.1
21	1.0	2.2, 1.8	0.5 to 0.7
22	1.1, 1.0, 1.0, 1.2, 0.8, 0.8, 1.4, 0.8	1.0	0.6
23	1.2, 1.4, 0.8		0.5
24	1.6, 1.7, 1.6, 1.5, 1.6, 1.9, 1.9		2.8
25	0.6, 0.6, 0.8		0.3
26	1.5, 1.3, 1.3		1.3
27	3.3, 2.7, 2.1, 1.8, 2.3, 2.0	2.9, 1.9, 1.9	7.5 to 10.0

EFFECT OF THE IRON CONTENT OF THE BUTTER WASH WATER

Little is known regarding the iron content of creamery waters and of the effect that it may have on the iron content of the butter.

Sonke Knudsen and Pape (3), state that a creamery water should not contain more than 0.5 p.p.m. of FeO. Other workers (6) cite an instance where a creamery water containing from 9 to 15 p.p.m. of iron was the cause of oily and tallowy butter. Kooper (4), on the other hand observed no detrimental effect from the use of a butter wash water re-constituted from distilled water and ferrous carbonate to contain 36 p.p.m. of iron, and yielding a butter calculated to contain 20 p.p.m. of iron.

For some time the iron content of creamery waters received by this laboratory for analysis has been determined by the procedure laid down in "Standard Methods of Water Analysis" (9). Of the 27 creameries reported in Table 1, iron analysis of the butter wash water was available for all but one creamery and will be found in the last column of Table 1.

Since the result in some cases is based on a single determination, and as there is likely to be a variation in the iron content of the water from time to time, particularly where it is pumped into a storage tank before going to the churn, the figures given should be considered only approximate. Nevertheless, they suggest a relationship between the iron content of the butter wash water and that of the butter.

To gain more definite information on this point, experimental churnings were made at a number of creameries. The plants selected used waters varying in iron content from less than 0.1 p.p.m. to 7.8 p.p.m., but were otherwise quite similar. The experimental procedure was as follows. After churning was completed and the buttermilk drained off, a portion of the butter granules was removed from the churn. The regular churning was then proceeded with as usual, which consisted of giving the butter granules a rinse until the water came nearly clear at the gate. The gate was then closed and enough water run in to float the granules and the churn revolved for a few minutes, the water was then drained off and the butter salted and worked. When the moisture content was low, water was added so as to have a moisture content of the finished butter of from 15.5% to 15.8%.

The butter granules removed from the churn were rinsed and washed with distilled water, worked and finished by hand. An effort was made to copy the regular churning procedure as closely as possible in regard to

TABLE 2.—THE EFFECT OF THE BUTTER WASH WATER ON THE IRON CONTENT OF BUTTER

Creamery	Chg. nos.	Iron content of butter		
		Washed with iron free water	Washed with creamery water	Iron content of creamery water
		p.p.m.	p.p.m.	p.p.m.
A	779	0.9	0.9	<0.1
	780	0.5	0.8	
	782	0.6	0.6	
	916	0.5	0.6	
B	163	0.4	1.05	3.2
	164	0.4	0.95	
	165	0.35	0.9	
C	450	0.6	0.9	0.1 to 0.2
	454	0.5	0.55	
	496	0.45	0.7	
	497	0.4	0.6	
	499	0.4	0.5	
D	609	0.5	0.5	<0.1
	610	0.45	0.45	
	612	0.4	0.4	
E	189	0.4	0.5	<0.1
	190	0.35	0.6	
	191	0.3	0.35	
F	(a)	0.65	1.6	2.8
	(b)	0.6	1.9	
	(c)	0.7	1.3	
G	301	0.4	0.6	0.4
	302	0.4	0.6	
	303	0.4	0.8	
H	246	0.5	1.6	7.8
	247	0.5	1.8	
	248	0.5	1.5	

washing and composition of the butter in order that the only essential difference between the 2 butters would be in the iron content of the butter wash water.

In Table 2 the results obtained from 27 such experiments at 8 different creameries are reported.

It is evident that the iron content of the butter wash water played a role in determining the amount of iron present in the butter. Where the iron content of the water was considerable it became a significant factor.

It will be observed that at creameries having a water low in iron, the iron content of the butter differed but little from that washed with distilled water and that there is a rather consistent tendency for the iron content of the butter to follow that of the water. It is worth pointing out that when the iron content of the water was low or when distilled water was used, the iron content of the butter was consistently less then 1.0 p.p.m. and often below 0.5 p.p.m., and that the butter was made from good quality cream and at plants where contamination from equipment was not likely to be a significant factor. (Creameries E, F and H had churns of the roller-less type.)

DISCUSSION

While the iron content of creamery butter heretofore has been given scant attention, it is likely that more interest will be shown as the butter market becomes more discriminating and the demand for a butter possessing superior keeping quality more pressing.

With our present incomplete knowledge of the effect of iron on butter it is rather difficult to evaluate properly iron analyses of butter, since factors other than total amount of iron evidently are involved. Barnicoat and Palmer (1) have thus recently shown that ferrous iron as compared to ferric is very much more active in catalysing oxidative changes in butter.

The work reported shows considerable variation between creameries in the iron content of their butter and a rather unexpected uniformity within the individual creamery. However, the fact that so many creameries were capable of producing butter with a low iron level gives promise that iron as a factor in butter deterioration may be largely overcome.

In the past much attention has been given to farm utensils as a source of the iron appearing in cream and butter. From the present study it is evident that the butter wash water may also be a factor and at plants where the iron content of the water supply is high, it may become necessary to resort to de-ironizing the water used for buttermaking purposes in order to bring about a reasonably low iron content in the finished butter.

SUMMARY

1. A total of 146 churnings of commercial creamery butter, representing 27 creameries have been analysed for iron.

2. The iron content of the butter ranged from 0.4 p.p.m. to 3.3 p.p.m. Of 123 first grade churnings 74% contained less than 1.5 p.p.m. Of 23 churnings below first grade 48% contained less than 1.5 p.p.m.

3. There was a tendency towards uniformity in the iron content of the butter from the same creamery, particularly for butter of first grade.

4. The iron content of the butter wash water was shown to affect the iron content of the butter.

5. When the butter was washed with distilled water or natural water low in iron, all of the first grade butter examined contained less than 1.0 p.p.m. of iron. An increase in the iron content of the butter wash water was usually accompanied by a higher iron content of the finished butter.

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AN ESTIMATE OF LOSS IN MANITOBA FROM COMMON ROOT ROT IN WHEAT[1]

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INTRODUCTION

Common root rot of cereals, caused chiefly by the fungi *Helminthosporium sativum* P.K. & B. and *Fusarium culmorum* (W.G. Sm.) Sacc., appears to be widespread in Canada and to cause considerable damage to cereals and grasses. These fungi invade the basal parts of the plant and bring about a reduction in tillering, and a stunting or wilting, or even the death of the host.

Losses from common root rot are difficult to estimate. The occurrence of disease in a field appears to be closely related to the physical and chemical structure of the soil, and, therefore, if the soil within a field is extremely variable, there is also a considerable variability in the severity of root rot in different parts of the field. The writer's observations during a 12-year survey, 1930 to 1941 inclusive, showed that common root rot was generally most severe where conditions for growth of the host plants were unfavourable. The following predisposing factors were found to increase the severity of the disease: the planting of frosted or mechanically-injured seed, deep or dense seeding, soil drifting, excessive soil salinity, and, low water-holding capacity of the soil. These findings were corroborated by Shen (3) who showed that low soil moisture, poor nutrition, and high soil-acidity foster the development of *Fusarium culmorum* root rot in wheat.

The loss from common root rot has been estimated in various ways. Simmonds (4) studied healthy and diseased plants of wheat and barleys in the field, and found that moderate lesioning on the sub-crown internode reduced the yield from 15 to 20%, and that severe lesioning reduced the yield from 30 to 45%. He did not report any loss from slight lesioning. Edson and his co-workers (2) summarized the individual estimates of loss obtained from field investigators in different parts of the United States. The loss varied in different parts of the country, but in some areas it was as high as 10%. Craigie (1), basing his estimate upon results from experimental plots at Winnipeg, found the annual loss from common root rot in Manitoba to be not less than 5%. Greaney[3] estimated the annual loss for Manitoba at 5%, for Saskatchewan at 9.4%, and for Alberta at 3%. This estimate was based on data obtained from plant disease surveys and from field experiments made by members of the Dominion Laboratories of Plant Pathology located at Winnipeg, Saskatoon, and Edmonton.

In view of the fact that previous estimates of loss from common root rot for Manitoba were based largely upon results obtained from experimental plots in which the conditions in regard to the spacing of rows and

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[3] Unpublished data of Dr. F. J. Greaney, Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba.

methods of cultivation were generally different from those found in actual farm fields, the writer attempted to devise a better method of securing an estimate of loss from common root rot. It was thought that, if the severity of root rot was related to the yield in individual plants, and if a sufficiently large number of plants were studied in several representative farm fields in each soil zone, the estimate of loss from common root rot would be reasonably accurate. In order to measure the loss from common root rot in wheat, 60 wheat fields were studied in Manitoba in each of the 3 years, 1939 to 1941 inclusive. The results of this study are summarized in this paper.

PROCEDURE

In order to secure a reasonably representative estimate of the loss from common root rot in wheat in Manitoba, it was necessary to obtain a large number of random samples of ripe, standing grain from all wheat-growing sections of the province. To aid in the collection of such representative samples, the writer outlined on a good road map of Manitoba the principal soil zones, and, in each soil zone, except in one (A2), which is very large, he selected 10 sampling locations, about equal distances from one another. Twenty locations were selected in the large soil zone.

Each year, as the wheat crop matured, the different sampling locations were visited, and at each location, one field of wheat was sampled. The field was entered to a distance of 50 paces and a sample of plants (all those in a 1-metre length of drill row) was taken at that point. At 9 other points, separated by 50-pace intervals and in a line roughly paralleling the margin of the field and 50 paces within it, other plant samples were taken in the same way. The whole group of 10 samples was then tied in a bundle, which was wrapped and marked with the sampling location number. After the whole wheat-growing area of Manitoba was sampled in this way, the bundles of plants were taken to the laboratory, each bundle was opened, and the plants within each were classified into groups according to the severity of root rot on them. The plants and the spikes in each group from a bundle were then counted. This count permitted, after the groups of plants from each bundle had been threshed separately, the computation of the average weight of grain per plant and per spike for each group.

In calculating the loss in yield for each collection from a field, use was made of the following formula:

$$\text{Percentage loss in yield} = 100 - \left(\frac{W}{W_1 \times N} \times 100\right)$$

where W is the total weight of grain from a collection, W_1 the average weight of grain from individual healthy plants, and N the total number of plants in a collection.

EXPERIMENTAL RESULTS

The average percentages of wheat plants with common root rot and the average percentage reduction in yield for each soil zone in each of the 3 years of the investigation are given in Table 1. The data given in this table indicate a considerable variation between soil zones in the percentage

of diseased plants, and perhaps even a greater difference between years. The percentage reduction in yield is not very closely related to the percentage of diseased plants when the data for individual soil zones in any one year are compared, but there is relatively close agreement in this respect when the data for the whole 3-year period or for all the zones are averaged.

TABLE 1.—THE AVERAGE PERCENTAGE OF WHEAT PLANTS WITH COMMON ROOT ROT AND THE AVERAGE PERCENTAGE REDUCTION IN YIELD FROM THE DISEASE IN DIFFERENT SOIL ZONES IN MANITOBA

Percentage of plants with root rot

Soil zone[1]	Year			Mean
	1939	1940	1941	
A1	29.2	47.3	32.9	36.4
A2 (W)[2]	24.3	50.8	52.8	42.6
A2 (E)	17.2	53.8	43.5	38.1
A3	20.5	65.2	40.2	42.1
A5	21.9	42.6	34.2	32.9
A7	16.2	50.6	46.6	37.8
Mean	21.5	51.7	42.7	38.3

Percentage reduction in yield

Soil zone	1939	1940	1941	Mean
A1	11.8	15.5	8.4	11.9
A2 (W)	7.5	15.6	21.7	14.9
A2 (E)	5.7	14.6	9.4	9.9
A3	5.6	13.7	14.1	11.1
A5	10.7	12.8	6.7	10.0
A7	6.7	26.4	12.3	15.1
Mean	8.0	16.4	12.1	12.1

[1] A1 Brown Steppe—Black Earth Transition.
A2 (W) Black Earth—Sandy over large areas.
A2 (E) Black Earth—Red River Valley clay loam.
A3 Northern Black Earth and Degrading Black Earth—Frequently highly salinized.
A5 Degrading Black Earth and grey wooded.
A7 Rendzina (High Lime).
[2] A2 (W) = Western part of A2.
A2 (E) = Eastern part of A2.

In Table 2 are given the average percentages of healthy plants and of those with slight, moderate, and severe root rot. There is much variation in the percentage of healthy plants from year to year, but, for any one year, or for any particular soil zone, the ratio of the percentages of plants with different degrees of disease remains fairly constant; the percentage of plants with slight root rot was about 2/3 of the total percentage of diseased plants. This marked preponderance of plants with slight root rot may not always be important. Simmonds (4), for instance, grouped healthy and slightly-lesioned plants together, apparently not attaching much importance to slight lesioning. In Manitoba, however, small lesions on the sub-crown

internode seem to have an adverse effect (Table 3) on yield. This reduction in yield arises chiefly from a reduction in the number of fruiting tillers and from a reduction in the weight of grain per spike. More pronounced reductions in the number of tillers and the weight of grain per spike accompanied moderate and severe root rot, which, in addition, reduced the length of culm. In practically all the plant samples that were collected from farm

TABLE 2.—THE PERCENTAGE OF HEALTHY PLANTS, AND OF PLANTS WITH SLIGHT, MODERATE OR SEVERE LESIONING BY COMMON ROOT ROT IN WHEAT FIELDS FROM DIFFERENT SOIL ZONES OF MANITOBA

Degree of root rot	Soil zone[1]	Year			Mean
		1939	1940	1941	
None	A1	70.8	52.7	67.1	63.6
	A2 (W)	75.7	49.2	47.2	57.4
	A2 (E)	82.8	46.2	56.5	61.9
	A3	79.5	34.8	59.8	57.8
	A5	78.1	57.4	65.8	67.1
	A7	83.8	49.4	53.4	62.2
	Mean	78.4	48.2	58.3	61.6
Slight	A1	19.4	27.4	19..	22.0
	A2 (W)	14.3	27.1	30.6	24.0
	A2 (E)	12.8	31.2	23.7	22.6
	A3	12.7	31.3	22.6	22.2
	A5	14.4	28.7	20.2	21.1
	A7	9.9	25.7	28.7	21.4
	Mean	13.9	28.5	24.1	22.2
Moderate	A1	8.5	15.1	11.2	11.6
	A2 (W)	8.1	18.0	18.3	14.8
	A2 (E)	3.7	18.2	17.0	12.9
	A3	6.3	23.5	14.3	14.7
	A5	6.9	11.6	12.4	10.3
	A7	5.3	18.8	15.4	13.1
	Mean	6.4	17.5	14.7	12.9
Severe	A1	1.3	4.8	2.4	2.8
	A2 (W)	2.0	5.7	3.9	3.8
	A2 (E)	0.7	4.4	2.8	2.6
	A3	1.5	10.4	3.3	5.0
	A5	0.6	2.3	1.6	1.5
	A7	1.0	6.1	2.5	3.2
	Mean	1.2	5.6	2.7	3.1

[1] See footnote in Table 1.

fields, the reduction in yield per spike was attributable to a reduction in the number of kernels, not to a reduction in the weight or size of kernel. In passing, it may be said that, in plant samples containing greenish-bronze kernels, the proportion of such off-colour kernels increased with an increase in the severity of root rot.

In Table 4 are summarized the data relating to the average density of stand, the average yield of individual plants and the average yield per acre. This information is provided so as to furnish some indication of the conditions in 1939, 1940, and 1941 for the growth of wheat in the different soil zones. It is difficult, however, to relate these conditions to the presence

TABLE 3.—THE REDUCTION IN THE YIELD OF GRAIN PER PLANT, NUMBER OF SPIKES PER PLANT, AND YIELD OF GRAIN PER SPIKE CAUSED BY DIFFERENT DEGREES OF SEVERITY OF COMMON ROOT ROT IN WHEAT

Year	Severity of disease		
	Slight	Moderate	Severe
Percentage reduction in yield per plant			
1939	27.5	41.5	72.6
1940	26.1	38.7	51.3
1941	23.5	32.3	48.1
Mean	25.7	37.5	57.3
Percentage reduction in number of spikes per plant			
1940	18.2	25.9	28.6
1941	23.2	27.8	36.2
Mean	20.7	26.8	32.4
Percentage reduction in yield per spike			
1940	10.0	16.6	24.1
1941	3.6	9.5	16.9
Mean	6.8	13.0	25.5

of root rot on the plants. In zone A1, the yield of individual plants was the highest, indicating the best conditions for growth, while, in zone A7, the yield was usually the lowest, indicating the poorest growing conditions. The difference in yield of individual plants may be partly accounted for by the fact that the plant population in zone A1 was much less dense than in zone A7. In spite of this difference in density of stand and in the individual yield, the percentage of plants with root rot (Table 1) on an average was about the same in these two soil zones. Other factors, no doubt, played an important part. The soil in zone Al was found to be sandy, low in nitrogen, and phosphorus, and subject to drifting. In zone A2(W) conditions were somewhat similar to those in zone A1, except that the soil was black instead of brown, indicating a greater organic matter content. Zone A2(E) was slightly deficient in phosphorus. Zone A3 was, in general, highly salinized,

and subject to soil erosion by wind and rain. The soil in zone A5 appeared to be good, except that occasionally organic matter was deficient or not well distributed. Zone A7 was very high in lime. Actually the conditions for growth in these zones were not very good, a fact which probably accounted for the prevalence of root rot on the crops grown there.

TABLE 4.—THE AVERAGE NUMBER OF PLANTS IN A FIELD SAMPLE AND THEIR AVERAGE YIELD, TOGETHER WITH THE AVERAGE YIELD OF GRAIN PER ACRE IN DIFFERENT SOIL ZONES OF MANITOBA

Soil zone[1]	Year 1939	1940	1941	Mean
	Number of plants in sample (10 m. of drill row)			
A1	308.3	315.9	301.6	308.6
A2 (W)	387.8	455.1	347.4	396.7
A2 (E)	399.1	366.2	382.1	382.5
A3	335.0	416.5	328.0	359.8
A5	411.7	410.7	352.0	391.4
A7	404.0	501.4	489.9	465.2
	Yield of individual plants			
	gm.	gm.	gm.	gm.
A1	0.791	1.060	1.152	1.001
Z2 (W)	0.567	0.423	0.741	0.577
A2 (E)	0.623	0.749	0.783	0.718
A3	0.786	0.575	1.121	0.827
A5	0.772	0.942	1.094	0.921
A7	0.483	0.544	0.526	0.517
	Yield per acre			
	bus.	bus.	bus.	bus.
A1	24.04	33.02	34.26	30.44
A2 (W)	21.68	18.98	25.38	22.01
A2 (E)	24.56	27.10	29.51	27.05
A3	25.97	23.66	36.26	28.63
A5	29.52	38.15	37.98	35.21
A7	19.24	26.89	25.41	23.84

[1] See footnote in Table 1.

DISCUSSION

The results of the present investigation show, if the methods of making the necessary determinations are correct, that the annual loss from common root rot in Manitoba is in the neighbourhood of 12%. The method used in determining this loss is open to certain criticisms, particularly in respect to the way in which the fields of wheat were sampled, but it seemed to be the only one that was practical under the circumstances of the investigation.

It was necessary to sample many fields, and the time allowed by the rapidity with which the crops ripened did not permit much time to be spent in any particular field.

A point also open to criticism is the method of calculating the loss in yield from common root rot. Diseased plants undoubtedly yielded less than healthy plants, but there is some question as to whether or not the differences in yield were entirely attributable to the presence of root rot. It is possible that the healthy plants profited somewhat in their competition with diseased plants for food and moisture, and that their yield per plant was higher than it would have been if all the plants had been healthy. In the fields examined, the severely diseased wheat plants among a dense stand of healthy plants were always less vigorous than similarly affected plants in comparatively light stands. It seemed that, in the dense stands, the diseased plants were actually being smothered by their healthy neighbours. As healthy and diseased plants occurred more or less at random in the fields, it was impossible to determine what the yield per plant would have been had all the plants been healthy; and, hence, it was impossible to determine to what extent the yield of the healthy plants was increased as a result of reduced competition from the diseased plants.

There is some doubt concerning the role played by weeds in wheat fields attacked by common root rot. It is a well-known fact that weeds reduce the yields of cultivated plants by competing with them for food and water. When a wheat plant is weakend by root rot, it is less well equipped than a healthy wheat plant to withstand the ill effects of such competition and consequently becomes weakened even further. Actually, in wheat fields with common root rot, a vigorous weed may effectively retard or even prevent the growth of a diseased wheat plant near which it grows. On this account, the weed in effect replaces the diseased wheat plant in providing competition with neighbouring healthy wheat plants and, as this competition is usually vigorous, the healthy wheat plant probably does not benefit at all from the reduced competition from a diseased wheat plant as would be the case if the weed was absent. Competition from weeds would seem to cancel out any improved nutritional conditions afforded the healthy wheat plants by the presence of the weaker, diseased wheat plants, while, at the same time, exerting a detrimental influence on the diseased plants themselves. It would seem, therefore, that, in weedy fields comparatively free from weeds, and that, as in Manitoba the percentage of weedy fields is large, the present estimate of loss from common root rot is not too high.

SUMMARY

Common root rot of cereals and grasses is widespread in Manitoba. During the period 1930 to 1941 inclusive, no wheat field in the province was found absolutely free from the disease. The average percentage of diseased plants and the average reduction in yield for the 3 years, 1939, 1940, and 1941, was estimated at 38.3% and 12.1%, respectively. An average for the 3 years showed that a slight attack by common root rot reduced the yield of individual plants by 25.7%, that a moderate attack reduced the yield by 37.5%, and that a severe attack reduced the yield by 53.3%.

Yields were decreased as the result of a reduction in the number of fruiting tillers and in the number of kernels per spike. Because the proportion of slightly diseased plants was usually high, most of the loss occurred in this class of plants.

The severity of common root rot in any one year varied greatly from soil zone to soil zone. There was no tendency, however, during the 3 years of this investigation, for the disease in severe form to be confined to any one soil zone.

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THE EFFECTS OF WHEAT GERM AND CORN GERM ON THE FEEDING VALUE OF CEREAL GRAINS FOR HOGS

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A series of feeding tests at this station during the past six years has indicated that corn and also wheat when fed as the basal part of the market pig ration result in the production of an excessively fat carcass and a rasher pattern of fat and lean distribution less desirable than from barley feeding. From other studies with hogs and with rats, it seems probable that wheat germ and perhaps also corn germ may contain a factor or factors which facilitates the synthesis of and/or deposition of body fat from dietary carbohydrate.

The position of wheat in Canadian agriculture gives special importance to information relative to its nutritive properties and peculiarities, and the hereinafter described test was designed to study the role which the germ of wheat may play in determining the food value of this cereal.

METHODS OF INVESTIGATION

General

To test the hypothesis that the special fattening properties of wheat and corn are due in part to substances in the embryo portion, it was planned to supplement germ-free barley with wheat germ and with corn germ; germ-free wheat with corn germ; and germ-free corn with wheat germ. In a parallel series, rations consisting (for the basal part) of each of these 3 grains were fed, as well as a third series employing germ-free samples.

Animals

Purebred Yorkshire pigs weaned at 56 to 60 days and started on test between 65 and 70 days of age were used. A minimum initial weight of 35 pounds was also demanded to exclude any obviously poor-doing animals. The design provided for one test using fall-born and a replicate using spring-born pigs. In each test the sexes were distributed to have equal numbers in each lot. Within these restrictions, the 120 pigs employed were alloted at random to individual pens, 12 pigs to each of 10 feeding lots.

Feed Mixtures

All feed mixtures were identical as to the protein-mineral supplement, the percentage make-up of which was: 40 meat meal, 25 linseed oilmeal, 15 fish meal, 10 bone meal, 5 limestone, 5 salt. Potassium iodide was incorporated at 0.2 ounce per 100 pounds of supplement.

Rations fed until the pigs reached 100 pounds weight consisted of 85 parts basal feed plus 15 parts of the above supplement. At the 100-pound weight, pigs were changed individually to the B ration, which differed from the first (A) ration only in containing 10% instead of 15% supplement. The B ration was fed until the pigs were marketed at 200 pounds. While on the A ration, each pig received daily 15 cc. of a feeding fish oil of 2000 A and 400 D potency.

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The basal feeds or mixtures in the several lots were as follows:

Lot I —Entire No. 2 yellow corn.
Lot II —Degermed corn—table corn meal, Ogilvie Flour Mills.
Lot III —Degermed corn 90% plus wheat germ 10%.
Lot. IV —Entire No. 2 amber durum wheat.
Lot. V —Degermed wheat—wheat hearts, Ogilvie Flour Mills.
Lot VI —Degermed wheat 97.5% plus corn germ 2.5%.
Lot VII —Entire No. 1 feed barley.
Lot VIII—Degermed Barley—pearl barley, Ogilvie Flour Mills.
Lot IX —Degermed barley 97.5% plus wheat germ 2.5%.
Lot X —Degermed barley 97.5% plus corn germ 2.5%.

The basis for the proportions of germ to be used was the percentage of embryo in the entire grain. Thus since in corn grain the embryo (i.e. the germ separation used) represented 10% of the weight of the kernel, one part of wheat germ was added to 9 of degermed corn so that the "remade" grain had its original proportion of embryo. Other basis could with equal justification have been used. Results obtained in this test must obviously be interpreted within the design employed.

Records

Both the weights of the pigs and their feed consumption were recorded every 14 days. The data presented herewith, however, apply to the complete feeding period from the start of the test to time of marketing. Carcass data were secured through the co-operation of the Marketing Service of the Department of Agriculture, whose graders cut and examined each carcass according to the plan followed in the case of Swine Advanced Registry pigs; and of Canada Packers, who kindly made available necessary abattoir equipment for examination and for freezing the sections in addition to absorbing the losses from the cutting of the carcasses.

Statistical Analysis

The design of the trial was such than an analysis of the variance was possible according to the following scheme:

TABLE 1.—SCHEME OF STATISTICAL ANALYSIS APPLIED TO ITEMS FOR WHICH DATA WERE RECORDED

Source of Variance	Degrees of freedom		
All causes—120 pigs			119
Between 40 subgroups			
2 sexes		1	
2 seasons		1	
10 rations		9	
Interaction			
Sex × Season	1		
Sex × Ration	9		
Ration × Season	9		
Sex × Ration × Season	9	28	39
Within subgroups (error)			80

RESULTS

The results of this test are summarized in Table 2 which gives the essential data for each feeding group.

It will be noted that in Table 2 only the average values for each group are given. However, from the variability of the individual animals, there has been calculated the difference between the averages of 2 groups in any item being compared (as daily gain, carcass score, etc.), which would be expected to occur once in 20 times by chance alone[3]. This figure, called the "necessary difference", is the allowance which must be made for variation due to factors other than ration differences. The odds are 19 to 1 that where differences between 2 group averages exceed the "necessary difference" for that item, there is a real effect of kind of ration. With this in mind, the data may be examined in some detail.

Rate of Gain

Rate of gain is indicated by the observed daily gains, by the gain adjusted for equal initial weight of pig and equal feed intake, and by number of days of feeding needed to get the pigs to market weight. The average daily gain for the whole test was 1.27 pounds; against which we may set figures of 0.82 pound and 0.92 pound for pigs on degermed corn and degermed wheat respectively; and 1.61 pounds and 1.57 pounds for entire barley and entire wheat respectively. There can be no doubt of the nutritional significance of the germ of these two cereals. For some as yet unexplained reason, loss of the germ from barley is much less serious, resulting in a decline in gain of but one-quarter of a pound per day.

Expressed in terms of feeding period, the use of degermed instead of entire cereals in these rations resulted in an increase equivalent to 60, 80, and 18 days feeding for corn, wheat, and barley respectively. It should be noted that some of the pigs on the degermed corn and degermed wheat rations were actually sent to market under weight, because they were making little if any gain at all. Had the test been carried until these pigs reached 200 pounds, the average gains for their lots would have been still lower.

Efficiency of Ration

If the differences in gains traceable to differing initial weights of pigs ($b_1 = 0.0189$) and to differing feed consumption during the test ($b_2 = 0.2765$) are taken into account, it is evident that appetite failure was not the only cause of the slowing of the gains on the degermed wheat or barley, for the feed efficiency (measured by "adjusted gains") was greater in all cases when the wheat germ was present. Furthermore, the addition of wheat germ to both degermed corn and degermed barley caused a definite increase in gains per unit of feed eaten. (Lots I *vs.* III; VIII *vs.* IX). On the other hand, corn germ was not an effective supplement to degermed wheat (Lot V *vs.* VI) or to degermed barley (Lot VIII *vs.* X).

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[3] Necessary difference between means $= \frac{\sigma}{\sqrt{n}} \times \sqrt{2} \times t_{p=.05}$.

TABLE 2.—EFFECTS OF WHEAT AND CORN GERM ON THE FEEDING VALUE OF CEREAL GRAINS

Character		Lot I Entire corn	Lot II Degermed* corn	Lot III Degermed Corn + wheat germ	Lot IV Entire wheat	Lot V Degermed* wheat	Lot VI Degermed wheat + corn germ	Lot VII Entire barley	Lot VIII Degermed barley	Lot IX Degermed barley + wheat germ	Lot X Degermed barley + corn germ	Nec.† dif. between lots	Male	Female	Nec.† dif. between sexes
Observed daily gain	lbs.	1.10	.82	1.35	1.57	.92	1.09	1.61	1.34	1.51	1.43		1.35	1.20	
Daily feed	lbs.	4.99	3.89	4.52	5.53	3.70	4.26	5.81	5.26	5.51	5.38		4.92	4.85	
Adjusted daily gain‡	lbs.	1.06	1.09	1.45	1.39	1.25	1.27	1.36	1.24	1.33	1.30	.09	1.35	1.20	.04
Days fed		144	170	111	102	161	142	98	116	103	114	10.5	107	125	5.24
Shipping weight	lbs.	200	173	198	203	183	198	202	202	201	202	5.13	196	204	2.56
Carcass length	ins.	30.0		29.6	30.4		29.6	30.2	30.4	30.1	30.3	.6	29.8	30.3	.3
Shoulder fat	ins.	2.0		2.0	1.8		1.8	1.7	1.8	1.9	1.8	.16	1.8	1.8	.08
Maximum belly	ins.	1.9		2.1	1.6		2.0	1.8	1.8	1.9	1.9	.13	1.9	1.9	.07
Belly grade§		3.2		3.4	2.3		3.2	1.7	2.3	2.4	2.7	.59	3.0	2.3	.29
Rail Grade—A		4		4	7		4	7	6	4	6		20	22	
B		7		7	5		8	5	6	7	6		27	24	
C		1		.						1			1	2	
Carcass score	%	59		52	71		54	77	69	64	63	8.36	61	66	4.18
Area loin	sq. in.	5.1		4.7	4.9		4.4	5.4	4.9	4.8	4.7	.45	4.6	5.1	.23
Per cent lean	%	37		35	40		35	44	39	37	39	3.63	37	39	1.81

*Carcass data incomplete, see page 81.

† Necessary difference $= \frac{\sigma}{\sqrt{n}} \times \sqrt{2} \times t_p = .05.$

‡ Gains adjusted by partial regression to equal initial weight (b_1 = .019 and equal feed intake (b_2 = .276).

§ Belly grade ranked from 1 (excellent) to 6 (poor).

Why corn germ was less effective in improving the gains per unit of feed eaten may perhaps be postulated from its content of certain parts of the vitamin B complex as compared to wheat germ.

Vitamin	Wheat germ	Corn germ
Thiamin gamma/gm.	27.9	6.5
Riboflavin gamma/gm.	8.2	3.8
Pantothenic acid gamma/gm.	18.1	11.0

It is true that more wheat germ was added to degermed corn than there was of corn germ added to degermed wheat, so that the quantity of vitamin B added was not equal in these two cases. But in the case of degermed barley equal amounts of corn or wheat germ were used. The wheat germ was more effective in raising rate of gain than was corn germ. The difference in ration efficiency was not significant though actually the wheat germ stood above corn germ. Since, however, the degerming of the barley caused much less nutritional damage, the comparative effects of wheat *vs.* corn germ supplement might not be very striking.

The question of feed efficiency and its relation to the germ fraction of the grains is further brought out by arranging the rations in descending order of gains made on equal feed intake:

TABLE 3.—RELATIVE FEED EFFICIENCY OF RATIONS

Ration	Relative live weight increase
Degermed corn plus wheat germ	137
Degermed wheat plus wheat germ	131
Degermed barley plus barley germ	128
Degermed barley plus wheat germ	125
Degermed barley plus corn germ	123
Degermed wheat plus corn germ	120
Degermed wheat	118
Degermed barley	117
Degermed corn	103
Degermed corn plus corn germ	100

Feed Intake

Animals on this test were full fed. Differences between lots in feed intake reflect differences in appetite. Evidently entire barley, degermed barley plus wheat germ, degermed corn plus wheat germ, and entire wheat were highly acceptable. In view of the known effect of thiamin on appetite, one might postulate that the higher thiamin content of these 4 rations

accounted for the high food intake in these lots. The results with degermed barley plus corn germ may have been tempered by the relatively high feeding value of degermed barley as compared to the other two grains.

Shipping Weight

The pigs in this test were marketed whenever they individually reached a predetermined live weight. The average shipping weight for all pigs was 201 pounds. As will be seen from Table 2, the male pigs were shipped at an average of 196 pounds and the females at 204 pounds. This was done deliberately in an attempt to correct the tendency for male pigs to be penalized for excessive fatness if marketed at equal weights with the females. This plan was reasonably effective in equalizing the carcass grades, but carcass scores, which include particularly size of eye of lean not considered in carcass grade, were still significantly below those for females.

Carcass Excellence

At the outset, it should be noted that no carcass data are included for the groups fed degermed corn or degermed wheat. There were several animals in each of these lots that were gaining so slowly that there seemed little hope of getting them to market at all. Accordingly when the trial was discontinued, these pigs were placed on other feed to be finished for market. The shipping weights shown for these lots are the figures to the close of the feeding on the experimental diet.

In general deficiencies in carcass excellence were traceable to the relative fatness. This is seen in several carcass measurements but best in "belly grade" in relation to "carcass score", "% lean" and to "thickness of belly". It will be noted that on the basis of carcass grade, the entire wheat and entire barley lots each had 58.5% grade A. In spite of this the entire wheat-fed hogs carried only 40% lean as compared to 44% lean in entire barley lots, and the eye of lean in the rasher was 4.9 square inches as compared to 5.4 square inches in the barley group. Thus wheat rations still produced the fatter carcasses. Had 10 pounds more weight been put on the male pigs it is our belief from examination of the carcasses that more wheat-fed grade A hogs would have been degraded to B class than would have been the case with barley-fed animals. It is of interest to note, however, that there appeared to be some advantage in considering sex in fixing marketing weights. We are unable to explain the significantly thinner bellies found on the wheat-fed pigs. It is not in accordance with previous or subsequent tests, nor does it correlate with other measurements which all indicate fatter carcasses in wheat-fed hogs.

The effect of adding wheat germ to degermed barley is evident in thicker bellies, and deeper shoulder fat, smaller percentage of lean, fewer A carcasses and smaller carcass score. Corn germ on the other hand has shown little effect in changing carcass characteristics over those produced on degermed barley without germ additions.

DISCUSSION

These data leave no doubt of the importance of the germ fraction in influencing the nutritional values of the cereal grains. Specifically it has been shown that much of the vitamin B complex is concentrated in the

embryo. Loss of this group of vitamins from the grains through milling processes alters materially the nutritive properties of the residue. On the other hand, milling fractions of cereals made up largely of the germ of the grain are likely to exhibit special nutritive properties when added to ration combinations, the nature and extent of which may be expected to be characteristic of the particular grain involved. It appears probable that these special properties are related to and perhaps proportional to the amounts of one or more members of the vitamin B complex rather than to any particular proteins or minerals present. This view is supported by rat feeding tests at this station (Crampton and Ashton, 1942; in press) in which diets comparable to the wheat lots of this study were compared to others in which synthetic vitamin B supplements replaced the cereal germ additions. The conclusions from that trial were (in part), "Corn germ and wheat germ are of markedly different nutritional value as supplements to a basal diet of wheat endosperm fortified with adequate proteins, minerals and vitamins A and D. . . . . . The intake through wheat germ of thiamin was about one-half, and of riboflavin one-third that fed in the (synthetic) B mixture. Feed intake was 34% greater with wheat germ supplement and 60% greater with the "B" mixture than in the check lot. Gains per unit of food eaten as a result of these supplements were 40% greater than in the check lot. Corn germ stimulated only an 18% increase in feed consumption and failed to improve the efficiency of the diet." (In these rat tests, wheat germ or corn germ was added as 2.1% of the total air dry feed.)

That one of the reasons for the fatter carcasses produced on diets in which wheat germ is present, is related to the fat synthesizing properties of thiamin seems evident from the results of tests on samples of the wheat germ and corn germ from our laboratory by McHenry and Patterson, School of Hygiene, University of Toronto. Wheat germ (4%) as the only source of any vitamin B components in their standard fat-free basal diet, produced in 7 days on amount of body fat equal to about 3 times that found in rats at the end of the 28 day preliminary feeding on the basal diet alone. Corn germ, however, failed to stimulate fat synthesis. They conclude[4], ". . . . There is equally good evidence for fat synthesis in group three (wheat germ) . . . No fat synthesis was produced by corn germ and this means, to us, almost complete absence of thiamin . . ."

The significance of these findings lies partly in the fact that a considerable number of cereal foods prepared for human consumption are carefully degermed during manufacture, usually to improve the keeping qualities of the product. The milling by-products containing the germ frequently find their way into animal feeds. Shorts from wheat, for example, contain about 40% of germ. Fed to dairy cattle, its vitamin B value is wasted. Fed with wheat or barley it may cause excessively fat carcasses. Fed with corn it might markedly improve the feed intake and hence the rate of gain of a corn ration, though there might be a tendency again toward fat carcasses.

[4] Correspondence to authors.

CONCLUSIONS

The nutritive properties of the cereal grain are in part dependent on the composition of their embryo fractions, probably specifically with their content of members of the vitamin B complex.

There appear to be differences between the germs of different cereal grains with respect to their nutritive properties. Wheat germ has an especially high value in supplementing the endosperm of corn, barley, or wheat.

Because of the tendency of wheat germ to stimulate or facilitate synthesis and deposition of body fat from dietary carbohydrate, it seems possible that use might be made of this characteristic to regulate, to some extent, the utilization of the food consumed by animals.

MANGANESE DEFICIENCY IN SOILS AND CROPS

II. THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY IN OATS[1]

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Marked response in the control of manganese deficiency of Alaska oats was obtained in 1940 by the writer (1) using a foliage spray of 1% $MnSO_4$. These oats were grown in a range at the Ontario Agricultural College, where oats invariably exhibited severe symptoms of manganese deficiency. Opportunity was afforded, during 1942, to supplement the earlier studies, on the aforementioned range, and on a large field of muck soil at Wallaceburg, Ontario, where oats are grown for processing into powdered grass.

INVESTIGATIONS

A. Experiments on the Range at the Ontario Agricultural College

Investigations were conducted to determine the optimum foliage spray concentration, with and without a spreader and sticker; the relative efficiency of foliage dusting with various manganese compounds; the minimum amount of manganese necessary as a soil application, and the contributory effect of gypsum and sulphur; also, the relative efficiencies of a fertilizer grade of manganese sulphate and of certain manganese ores when compared with pure manganese sulphate.

Materials and Methods

Erban oats were sown on April 30, in the manganese-deficient soil in plots, each consisting of 4 rows, 8 inches apart and 66 feet long. Check plots, 5 weeks after sowing, gave the following analysis expressed as lb. per acre: phosphorus high (P_2O_5 = 130 using 0.05 N HCl, modified Thornton); potassium high (K_2O = 450, Thornton); calcium medium high (Ca = 1000, Spurway); magnesium high (Mg = 56+, Spurway); free carbonate = 0. In reaction the soil was very slightly alkaline (pH 7.2). The soluble manganese content of this soil was found to be 0.9 p.p.m. while that of neighbouring soil where manganese deficiency of oats does not occur was 4.0 p.p.m. The manganese determinations were made by the Soils Division, Chemistry Dept., Ontario Agricultural College, by a technique as yet unpublished.

The manganese compounds included: manganese sulphate ($MnSO_4 \cdot 4H_2O$); Tecmangam, a manganese fertilizer containing 66.99% $MnSO_4$. 10.00% $(NH_4)_2SO_4$, 22.40% $MgSO_4$, along with traces of eleven other elements; and three manganese ores which contain, among other elements, manganese in the oxide form, and designated as Frit JW325 (30% Mn),

[1] Contribution from the Department of Botany, Ontario Agricultural College, Guelph, Ontario.
[2] Assistant Professor of Botany.

Frit (FW325 (7.07% Mn), and Frit 12% Mn (12% Mn). The Tecmangam and Frits were supplied by The Harshaw Chemical Company, Cleveland, Ohio.

Soil applications of the various manganese compounds (see Table 1) were made by sifting the compound uniformly within a trench 6 inches deep, filling the trench with earth and sowing the oats directly above. Gypsum and sulphur were applied, separately, on certain of the plots, alone and in combination with Tecmangam. They were applied at the rate of 1000 lb. per acre by surface broadcasting, following which the soil was disced to a depth of about 6 inches, then levelled. This was done prior to manganese application or sowing.

Foliage spray applications of $MnSO_4$ and Tecmangam were made with a knap-sack sprayer on June 5, five weeks after sowing. At this time the oats were slightly chlorotic, an early symptom of manganese deficiency. The $MnSO_4$ and the Tecmangam were applied at rates varying from $\frac{1}{4}$% to 5% (see Table 1) with and without a spreader and sticker (bentonite clay $\frac{1}{2}$% and soap 1 oz. per gallon).

Dust applications of all the manganese compounds were made on the respective plots, on June 6. The dust was applied by means of a hand duster in the early morning when the foliage was wet with a heavy dew. The amount of dust applied was made equivalent in manganese content to that of a 1% $MnSO_4$ spray; this resulted in a very heavy load of the Frit dusts, especially those of a low manganese content.

Each plot was divided at harvest as 3 replicates. The sheaves were hung in a barn until thoroughly dry then weighed, threshed, and the resultant grain cleaned of all chaff and weighed.

TABLE 1.—DATA ON THE RESPONSE OBTAINED FROM THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY OF ERBAN OATS

Method of application	Compound and rate of application*		Data on the response obtained is given as average of three replicates; where significant variations occurred the extremes are included			
			Plant height/ inches	Sheaf weight (air dry) lb./acre	Grain weight bu./acre	Remarks
—	Check		20 (15–30)	1500	3 (0–4)	Excess tillering gave high sheaf weight; mostly leaves
Foliage dust	Frit 12% Mn	Dosage equal in Mn content to 1% $MnSO_4$ spray	28 (21–34)	2344	19	Severe symptoms of manganese deficiency
	Frit JW325		25 (21–32)	1641	8	
	Frit FW325		26 (23–34)	1641	8	
	Tecmangam		39	3516	38	Considerable foliage burning especially with $MnSO_4$. New growth of normal colour
	$MnSO_4$		40	3117	30	

* The −S and +S within the foliage spray technique refer to the absence and presence, respectively, of a spreader and sticker along with the manganese spray.

TABLE 1.—DATA ON THE RESPONSE OBTAINED FROM THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY OF ERBAN OATS—*Continued*

Method of application	Compound and rate of application		Data on the response obtained is given as average of three replicates; where significant variations occurred the extremes are included			
			Plant height/ inches	Sheaf weight (air dry) lb./acre	Grain weight bu./acre	Remarks
Foliage spray	Tecmangam ½%	−S*	33	2273	14	Later stages of growth not as vigorous as in in those plots where a heavier spray concentration was used
		+S	36	3281	31	
	$MnSO_4$ ½%	−S	36	2742	21	
		+S	39	3352	34	
	Tecmangam 1%	−S	39	3281	30	No foliage burning by the spray
		+S	39	3914	39	
	$MnSO_4$ 1%	−S	37	3281	31	
		+S	40	3586	34	
	Tecmangam 2%	−S	41	3984	37	Some burning of foliage observed but new growth normal
		+S	42	4219	44	
	$MnSO_4$ 2%	−S	43	3750	37	
		+S	43	4453	46	
	Tecmangam 5%	−S	43	3984	41	Severe burning after spraying which checked growth temporarily
		+S	41	4383	44	
Soil application/lb. per acre	Frit 12% Mn 250		22 (20–34)	1172	3	Severe symptoms of manganese deficiency
	Frit JW325 250		22 (20–31)	1172	7	
	Frit FW325 250		22 (20–31)	1641	9	
	Tecmangam 370		40 (35–45)	3914	33 (13–46)	Irregular stand
	Tec. 370 + Gypsum 1000		35 (15–42)	2051	12 (3–22)	
	Tec. 370 + Sulphur 1000		45	5927	58	Growth of normal appearance
	Tecmangam 925		47	5555	53	
	Tec. 925 + Gypsum 1000		43	5086	63	
	Tec. 925 + Sulphur 1000		47	6633	79	Luxuriant growth
	Tecmangam 1850		49	6094	63	No evidence of manganese toxicity
	$MnSO_4$ 250		42 (40–44)	3750	33 (20–51)	Irregular stand
	$MnSO_4$ 625		48	6797	76	Luxuriant growth
	Gypsum 1000		—	—	—	Yields not recorded; no improvement over check plots
	Sulphur 1000		—	—	—	

Observations and Conclusions

Data on the response obtained by the various manganese compounds and the techniques of application are presented in Table 1. The yields are given on an acreage basis as an average of the 3 replicates except where wide differences between replicates occurred; in the latter instances the extremes of the replicates are included along with the average.

The check plots began to show chlorosis about 5 weeks after sowing. Typical symptoms of manganese deficiency then developed. In some portions of the plots no heads developed while in others spindly heads were formed which, as indicated in Table 1, yielded little grain. Excess tillering of the oats resulted in a relatively high sheaf weight in proportion to grain weight.

FIGURE 1. Response of Erban oats to soil applications of various compounds to correct manganese deficiency. The plot to the left received gypsum at 1000 lb. per acre; centre was a check; to the right received Tecmangam at 925 lb. and sulphur at 1000 lb. per acre. The portion of the plot shown at upper extreme left received a foliage spray of ½% $MnSO_4$ without a spreader and sticker.

The Frits gave only a minor response when dusted on the foliage even though the dosage was sufficient to give an equivalent in manganese content to that of a 1% $MnSO_4$ spray. The Tecmangam and $MnSO_4$ applied as dusts gave results comparable to a 1% spray of these compounds but rather severe foliage burning occurred. This burning might have been avoided had an inert dust diluent been used.

All plots receiving the various foliage spray concentrations of Tecmangam and $MnSO_4$ showed an initial response about 10 days after application, and, a few days later, presented a sharp contrast to the check plots because

of their dark green colour and more rapid rate of growth. Foliage burning by the 2% sprays camouflaged the initial response to some extent; this burning was most evident in the 5% Tecmangam spray plot, where growth was temporarily checked. Later field observations, substantiated by the yield data (see Table 1) indicated that of the 4 spray concentrations used, the 2% spray was the most efficient. In all instances a better yield was obtained when the spreader and sticker was added.

Soil applications of the Frits gave little to no response. Lack of sufficient material prevented testing these Frits at higher rates of application than 250 lb. per acre. The response to Tecmangam alone depended upon application rate: 370 lb. per acre gave an irregular stand with a corresponding irregularity in grain yield within different replicates; 925 lb. per acre gave a uniform stand of normal appearance while 1850 lb. per acre resulted in a luxuriant stand and the highest yield. Application at the rate of 1850 lb. per acre is probably far beyond maximum requirement but, contrary to expectations, no evidence of manganese toxicity was observed even though the compound was sown as a row underneath the seed grain.

The response to soil applications of $MnSO_4$ followed a pattern comparable to that of Tecmangam. $MnSO_4$ at the rate of 250 lb. per acre resulted in an irregular stand similar to that of Tecmangam, applied at the rate of 370 lb. per acre. This could be expected in that Tecmangam contains approximately 67% $MnSO_4$. Application of $MnSO_4$ at the rate of 625 lb. per acre resulted in a luxuriant stand and a grain yield of 76 bushels per acre.

Gypsum and sulphur were applied to the soil at the rate of 1000 lb. per acre, alone and in combination with different application rates of Tecmangam. Alone, neither gypsum nor sulphur gave any response. Any beneficial effects obtained from the use of gypsum in combination with Tecmangam are questionable. Sulphur, on the other hand, contributed markedly. Tecmangam at the rate of 370 lb. per acre with sulphur gave a slightly higher yield than Tecmangam alone at the rate of 925 lb. per acre. Sulphur along with Tecmangam at 925 lb. per acre gave the highest yield of any plot (79 bushels per acre).

A comparison of the 3 techniques of applying manganese, that is, foliage dusting, foliage spraying, and soil application, would indicate that the highest yield can be obtained by soil application. From an economic viewpoint, however, the soil application technique is open to question. Tecmangam, alone, at the rate of 925 lb. per acre, or at the rate of 370 lb. plus sulphur at 1000 lb. per acre were required to exceed the grain yield obtained by a 2% spray. The extra cost of materials for soil application would more than counterbalance returns from the increase in yield. Severe foliage burning could be expected if dusting were substituted for the 2% spray. This might be avoided, however, by including some inert dust diluent.

B. Experiments on the Use of Tecmangam to Correct Manganese Deficiency of Oats, on a Field at Wallaceburg, Ontario

Oats grown on a large flat field at Wallaceburg, Ontario, have expressed mild to moderate symptoms of manganese deficiency, especially during dry seasons. These oats are grown for processing into powdered grass. Three to 5 cuttings are usually made from 1 sowing, the first cutting being made just prior to nodal establishment.

Materials and Methods

The soil is a well decomposed muck containing a moderately high amount of organic material and considerable fine sand. Soil samples taken the latter part of April, 1942, gave the following analysis expressed as lb. per acre: phosphorus high (P_2O_5 = 150 using 0.05N HCl, modified Thornton); potassium low (K_2O = 60, Thornton); calcium medium high (Ca = 1000, Spurway); magnesium high (Mg = 56+, Spurway); free carbonates = 0. In reaction the soil was slightly acid (pH 6.5).

Plots were established in this field to ascertain the response which could be obtained by soil applications of Tecmangam applied at various rates and by a foliar dust application. Table 2 gives the different rates of application which varied from 68 lb. to 619 lb. per acre. Each plot (0.97 acres) consisted of two strips 8 feet wide and ½ mile long with a 2-foot border left unplanted between the strips. The two strips of any one plot were not adjoining but were harvested as a single unit. Because of insufficient material, a single strip constituted the plot for the heaviest application of Tecmangam (619 lb. per acre).

Boone oats were sown on May 19, 1942, using an 8-foot seed drill. By means of a fertilizer attachment to the drill, 0-12-15 fertilizer was applied to all the plots at the rate of 200 lb. per acre. The respective soil applications of Tecmangam (see Table 2) were made by mixing the Tecmangam with the 0-12-15 fertilizer. The dust application of Tecmangam involved mixing the compound with "overs" (screenings from the powdered grass) at the rate of 5 lb. of Tecmangam to 8 lb. of "overs". This mixture was dusted on the foliage on June 13 (25 days after seeding) at the rate of 60 lb. per acre. This gave an approximate equivalent in manganese content to a 1% $MnSO_4$ spray.

The oat grass was cut by power equipment, then in the processing equipment, dried rapidly, ground, cleaned and bagged as a fine dry powder. The weight of the refined powdered grass was used to calculate the yield. The manganese content of the powdered grass was determined on a dry weight basis by a slight modification of the Willard and Greathouse method. Data were obtained from the first two cuttings only.

Observations and Conclusions

Data on the yield and the manganese content of the powdered grass from the first 2 cuttings are presented in Table 2. The check plot exhibited mild symptoms of manganese deficiency at the time of the first cutting. As may be seen in Table 2, both the yield and the manganese content of the

powdered grass, obtained from the first cutting, indicated a response to soil application of Tecmangam, which was directly proportional to the rate of application.

No symptoms of manganese deficiency were evident on the check plot at the time of the second cutting. Wet weather may have influenced the availability of the natural soil manganese. Compared with the first cutting, the yield of the check plot was doubled and was even higher than that of any of the plots in which applications of Tecmangam had been made. Some response to the various rates of soil applications of Tecmangam was indicated by the yields of the second cutting. The exception to this was the plot in which Tecmangan had been applied at the rate of 272 lb. per acre. No explanation can be given by the writer for the relatively high yield of this plot. The responses obtained from the various soil applications of Tecmangam, as expressed by the manganese content of the powdered grass, were at a lower level than those obtained in the first cutting.

TABLE 2.—RESPONSE TO MANGANESE BY BOONE OATS FROM WHICH SUCCESSIVE CUTS WERE MADE FOR PROCESSING INTO POWDERED GRASS

Tecmangam[1] Application lb./acre	Yield and Mn. content of the powdered grass on a dry weight basis			
	1st cut—June 20[2]		2nd cut—July 7	
	Yield lb./acre	Mn content p.p.m.	Yield lb./acre	Mn. content p.p.m.
Check—0	374	19.9	753	17.1
Soil—68	422	21.0	777	27.3
Soil—136	425	36.2	802	21.4
Soil—272	508	49.9	1030 ?	41.9
Soil—619	684	86.7	865	54.8
Foliage dust—23	454	47.7	588	35.5

[1] Tecmangam—A commercial fertilizer containing 67% $MnSO_4$.
[2] The first cut was made just prior to jointing.

The foliage application of Tecmangam as a dust mixed with powdered grass screenings caused no foliage burning but did not have an opportunity for full expression. Response to foliage application of manganese is not visibly evident until at least 7 to 10 days after application; only 1 week elapsed between dusting with Tecmangam and the first cutting.

SUMMARY

Various techniques were employed to determine the most practical means to correct manganese deficiency of Erban oats on soil where oats normally express severe deficiency symptoms.

1. Very heavy applications of compounds containing manganese sulphate were required as soil application to correct the deficiency in Erban oats. The addition of sulphur at the rate of 1000 lb. per acre increased the yield materially and in one instance reduced the amount of manganese necessary by about two-thirds.

2. Of the spray concentrations tested, a single 2% spray of $MnSO_4$ or of Tecmangam (67% $MnSO_4$) with a spreader and sticker added, resulted in the highest yield. Some foliage burning occurred. The spray did not give as high a yield as the heavy soil applications. Nevertheless, this lower yield is more than counter-balanced by the added cost of materials for soil application.

3. Foliage dusting with manganese sulphate and Tecmangam, without a dust diluent caused severe foliage burning.

4. Three manganese ores tested as soil applications at 250 lb. per acre or as foliage dusts equivalent in manganese content to a 1% $MnSO_4$ spray gave little to no response.

Soil applications of Tecmangam at rates varying from 68 lb. to 619 lb. per acre were made on a large muck field where oats normally express mild to moderate symptoms of manganese deficiency. Successive cuts were made from these oats for processing into powdered grass.

1. Mild symptoms of manganese deficiency were evident on the checks at the time of first cutting (just prior to jointing). Both the yield and manganese content of the powdered grass indicated a response which was directly proportional to the amount of Tecmangam added.

2. No symptoms of manganese deficiency were evident on the checks at the time of the second cutting (17 days later). The manganese content of the powdered grass indicated a response to the Tecmangam but no definite correlations could be made with respect to yield.

ACKNOWLEDGMENTS

The writer is indebted to the Harshaw Chemical Co., Cleveland, Ohio, for supplies of manganese compounds; and to the Greenmelk Co., Wallaceburg, Ontario, for conducting certain of the field experiments. Thanks are also expressed to Mr. T. J. Heeg, Chemistry Department, Ontario Agricultural College, Guelph, Ontario, for soil analyses and manganese determinations; to Mr. J. W. Connor for technical assistance; and to Mr. W. D. Tolton, Extension Department for the photograph.

REFERENCE

1. MACLACHLAN, J. D. Manganese deficiency in soils and crops. 1. Control in oats by spraying; studies of the role of soil micro-organisms. Sci. Agric. 22 : 201-207. November, 1941.

ADDENDUM

Erban oats were sown in 1943 on the entire range of manganese-deficient soil and on adjoining normal soil at the Ontario Agricultural College. Manganese-deficiency symptoms began to appear 3 weeks after sowing; this was earlier than usual and can possibly be attributed to a temporary period of warm dry weather. It was of interest to note that there was no evidence of response to the heavy soil applications of $MnSO_4$, either with or without sulphur, applied the previous year. In view of the relatively small amount of foliage when deficiency symptoms began to appear, 2 sprays were applied, 3 and 5 weeks, respectively, after sowing. A 240-gallon orchard power sprayer with gun attachment was used. The spray contained Tecmangam 1%, bentonite clay ½%, and Orvus (Proctor and Gamble, Toronto) at the rate of ½ pint to 80 gallons. Although no yield data were taken observations throughout the growing period and at harvesting time indicated no difference between oats growing on normal soil and the sprayed oats on the manganese-deficient soil. A normal crop was obtained.

STUDIES RELATING TO FERTILITY IN ALFALFA (*MEDICAGO SATIVA* L.)

I. POLLEN VIABILITY AS AFFECTED BY SEASONAL AGE OF THE PLANT[1]

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The seasonal variability in pod-setting of the alfalfa plant is quite marked, and has been reported by numerous workers. That pollen viability might be involved was thought possible, and in 1936 an experiment was conducted to determine whether the pollen viability changed with an advance in the seasonal age of the plant.

LITERATURE REVIEW

Working with 3 species of the genus *Crepis*, Poole (11) made daily counts of the good and bad pollen produced by plants from the beginning to the end of the flowering period. From these counts he came to the following conclusions. "Fluctuation in the percentages of good and bad pollen in pure species is probably not influenced by external factors but by the physiological adjustments made to flowering and senescence." "The plotted curve of good pollen grain percentages substantiates this view, indicating further that the daily fluctuation is inconsiderable in a given plant once the adjustments are made."

TABLE 1.—LIST OF PLANT MATERIAL USED

Plant designation	Strain and plant number	Varietal origin	Flower colour	Growth habit	Fertility classification
1	S_3.33.3 (4-5)	Ontario variegated	dark purple	erect	sterile
2	S_1.28.3 (9-11)	Grimm Grafton's	yellow	erect	sterile
3	S_1.32.29 (40-10)	Grimm Lyman's	light purple	erect	fertile
4	I.31.9 (21-23)	Grimm	light purple	erect	fertile
5	S_1.32.32 (47.5)	Cossack	bluish	erect	fertile

MATERIALS AND METHODS

In this study 5 individual plants were used. Table 1 includes information regarding two of the important morphological characters of the plants, as well as the varietal origin and fertility rating. All of these plants were collected and classified by Bolton (3), and were grown in a large isolation screenhouse.

With one exception, the plants are considered to be representatives of the species *Medicago sativa* L. Plant 2, which could be classed as *M. media* Pers., has yellow flowers, pods which are slightly coiled, and extremely erect stems.

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[1] A portion of a thesis presented to the Committee on Graduate Studies, University of Alberta, in partial fulfilment of the requirements for the degree of Master of Science.
[2] Formerly Graduate Assistant, Department of Field Crops, University of Alberta, Edmonton; now on active service.
[3] Professor of Genetics and Plant Breeding, Department of Field Crops, University of Alberta, Edmonton.

Percentage pollen germination on an artificial medium was taken as a measure of pollen viability. The germination counts were made using the same method as outlined by Bolton and Fryer (4).

The medium consisted of 1½ grams of agar and 12 grams of cane sugar in 100 cc. of water. The agar-sugar solution was poured into Syracuse dishes and used as soon as cooled. Pollen was spread over the medium by artificially tripping several flowers a few inches above the surface, 2 plates being prepared for each plant. The plates were covered, and the pollen allowed to germinate for 2 hours at room temperature (20 to 23° C.), after which they were placed in a refrigerator at approximately 0° C. until such time as the counts could be made.

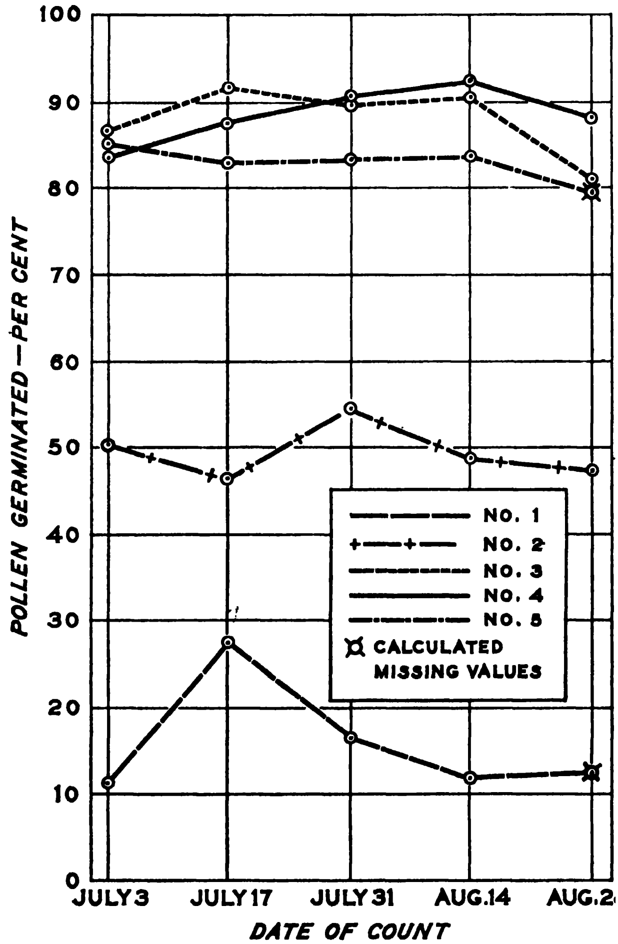

FIGURE 1. Pollen viability throughout season, expressed as percentage germination on agar-sugar medium.

Counts were taken of 100 microscopic fields for each plate, using the 16 mm. objective and 10× eyepiece. To facilitate the counting, the plates were flooded with a dilute solution of methylene blue chloride. A pollen grain was considered to have germinated if the length of the pollen tube was greater than the diameter of the grain itself.

The same procedure was followed throughout the flowering season at 14-day intervals, the pollen being spread on the agar-sugar medium at about the same time of day on each occasion.

The statistical analyses were carried out in accordance with the methods outlined by Fisher (10) and Snedecor (12). The inverse-sine transformation was applied to the percentage data following suggestions given by Cochran (8), and Clark and Leonard (6).

EXPERIMENTAL RESULTS

The plants used for this experiment were selected for a wide range in pod-setting ability, selection being based on determinations made by Bolton (3). The average percentage of pod-setting for these plants is presented below, the average being for 2 selfing tests conducted by Bolton (3) in the summer of 1935.

Plant designation	Pod setting (Per cent)
No. 1	0.00
No. 2	11.67
No. 3	22.23
No. 4	56.37
No. 5	83.35

The results obtained for the pollen viability counts are presented in Table 2 and shown graphically in Figure 1.

TABLE 2.—POLLEN VIABILITY AS AFFECTED BY SEASONAL AGE OF THE PLANT, EXPRESSED AS PERCENTAGE GERMINATION ON AGAR-SUGAR MEDIUM

Plant designation	Date	Number of microscopic fields counted	Total number of pollen grains	Number of grains germinated	Germination	
					Plate 1	Plate 2
					%	%
1	3/7/36	80	205	24	11.71	—
	17/7/36	200	1708	470	29.17	25.43
	31/7/36	150	410	67	19.28	7.69
	14/8/36	158	652	78	13.39	7.55
	28/8/36	no flowers available				
2	3/7/36	200	1863	937	47.83	52.38
	17/7/36	200	3584	1662	44.03	48.33
	31/7/36	200	2236	1233	55.70	54.54
	14/8/36	200	3338	1633	45.91	51.87
	28/8/36	200	2347	1112	49.82	45.09
3	3/7/36	200	2400	2081	87.70	85.85
	17/7/36	200	1724	1578	91.05	92.06
	31/7/36	200	1397	1252	86.05	90.95
	14/8/36	200	2325	2103	91.29	89.65
	28/8/36	200	1609	1303	81.71	80.33
4	3/7/36	200	2908	2444	82.94	85.51
	17/7/36	200	2103	1845	87.94	87.46
	31/7/36	200	1289	1166	92.41	88.66
	14/8/36	200	2149	1982	92.08	92.37
	28/8/36	200	1949	1712	87.74	87.93
5	3/7/36	200	3069	2611	83.93	86.40
	17/7/36	200	2379	1974	84.10	81.63
	31/7/36	200	1722	1433	81.19	84.51
	14/8/36	200	2591	2170	83.47	84.09
	28/8/36	no flowers available				

For purposes of analysis, the inverse-sine transformation was applied to the percentage data. Further, it was thought advisable to make two analyses because one count was incomplete and two others were missing. Table 3 gives the transformed data for all 5 plants at 3 different dates, and Table 4 for 3 plants at the 5 dates.

TABLE 3.—TRANSFORMED POLLEN GERMINATION PERCENTAGE DATA FROM TABLE 2, FOR 5 PLANTS AND 3 DATES

Plant designation	Date					
	17/7/36		31/7/36		14/8/36	
	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2
1	32.71	30.26	26.06	16.11	21.47	16.00
2	41.55	44.03	48.27	47.58	42.65	46.09
3	72.64	73.68	68.11	72.54	72.84	71.28
4	69.64	69.30	74.00	70.36	73.68	74.00
5	66.50	64.60	64.30	66.81	66.03	66.50

* Expressed as degrees, and obtained from transformation tables given by Bliss (2).

TABLE 4.—TRANSFORMED POLLEN GERMINATION PERCENTAGE DATA FROM TABLE 2, FOR 3 PLANTS AND 5 DATES*

Plant designation	Date									
	3/7/36		7/17/36		31/7/36		14/8/36		28/8/36	
	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2
2	43.74	46.38	41.55	44.03	48.27	47.58	42.65	46.09	.44.89	42.19
3	69.47	67.94	72.64	73.68	68.11	72.54	72.84	71.28	64.67	63.65
4	65.57	67.62	69.64	69.30	74.00	60.36	73.68	74.00	69.47	69.64

* Expressed as degrees, and obtained from transformation tables given by Bliss (4).

The analysis of variance, in degrees, for 5 plants at 3 dates is:

Variance due to	D.F.	M.S.	F	5% point
Plants	4	2,634.3877	92.05	3.84
Dates	2	5.5908	0.20	—
Plants × Dates	8	28.6204	—	—
Residual	15	6.6708	—	—
Total	29			

The analysis of variance, in degrees for 3 plants at 5 dates is:

Variance due to	D.F.	M.S.	F	5% point
Plants	2	2,129.2827	170.13	4.46
Dates	4	23.1048	1.85	3.84
Plants × Dates	8	12.5153		
Residual	15	2.5647		
Total	29			

It is clearly seen, from the two foregoing analysis tables, that difference in pollen viability due to dates is insignificant, while that for plants is highly significant. Therefore, it is concluded that under the conditions of this experiment, the pollen viability of a given plant does not vary significantly throughout the season.

DISCUSSION

The results obtained indicate that the seasonal variation in pollen viability for a given plant is not significant. This is in agreement with the work of Poole (11) for species of *Crepis.*

It is of interest to note that Poole (11) used plants grown in the greenhouse, whereas these studies were made on plants grown outside. The temperature and humidity would doubtless be more constant in the greenhouse than in the field.

In the field, temperature varied from 36° to 94° F., and the humidity from 20% to 100% during the course of the experiment. These varying conditions, however, had little effect on pollen viability, as is shown by the results obtained.

Clarke and Fryer (7) grew clonal divisions of the same plant in the greenhouse under conditions of high and low temperatures. The actual temperatures were not specified. They found that the temperature had no effect on the amount of poor pollen formed by the plant. Results also indicate that the variable percentages of viable pollen produced by the individual plants may be, in part, responsible for the differences exhibited in pod-setting.

This same view has been expressed by several workers. Engelbert (9) was of the opinion that 22.5% sterile pollen was of little importance when a plant produced an abundance of pollen, but that the amount and sterility of pollen may be partly responsible for differences in seed-setting exhibited by different plants. Brink and Cooper (5) concluded that the amount of abnormal pollen may occasionally be large enough to limit seed-setting. Armstrong and White (1) believe that pollen sterility is a factor which influences the pod-setting and the number of seeds per pod. Bolton and Fryer (4) report that there is no general correlation between pollen viability and pod-setting, even though there seems to be a relationship in some instances.

SUMMARY

Pollen viability counts were made on 5 alfalfa plants at intervals throughout the flowering season in 1936 at Edmonton, Alberta. The results of these counts indicate that there is no significant difference in pollen viability throughout the season on any one plant, but that differences between plants may be highly significant. Therefore, the seasonal variations in pod-setting cannot be due to changes in pollen viability.

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THE PHYSIOGRAPHY OF SOUTHWESTERN ONTARIO

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This is the third article dealing with the surface features of southern Ontario. The first two covered the central and eastern sections leaving the peninsular part, up to and including the Niagara Escarpment, to be described at this time. This area measures 225 miles from east to west along Lake Erie and averages 135 miles from Lake Erie to Georgian Bay, while the Bruce Peninsula projects 60 miles further to the northwest. It is one of the best farming districts of Canada, comprising 95,000 farms (10 million acres), and has one and one-quarter million inhabitants. For an area of its size it has a wide range of climate; the lowlands bordering the Great Lakes have longer summers and less rainfall than the higher hinterland. Since it is a glaciated region the soils are young and variable; the variations resulting mainly from differences in topography, depth to bedrock, manner of deposition and the nature of the surface drift. This account of the physiography of Southwestern Ontario discusses those differences. It is based on three summers field work and available geological information. In addition to its contribution to an understanding of the soils it is hoped that it will stimulate an appreciation of the landscape.

BEDROCK

The build of the region is due to the bedrock. This in turn governed the movement of the glaciers; that is, they advanced through the lowlands or flowed around the uplands, and the distribution of the glacial deposits followed. Glacial till invariably contains some foreign rock imported by the glacier. However, it is usual to find that a high proportion of the material comes from the underlying formations. The names of the various local rocks will be mentioned throughout this report, so that for these reasons it is well to discuss bedrock at the outset.

Figure 3 was copied from maps of the Geological Survey of Canada and shows the distribution of the several formations. The oldest strata appear along the eastern border and these are overlapped by younger layers of dolomite, shale, sandstone or limestone. The sandstone beds are thin and this rock does not appear extensively at the surface. The shale is in three bands of which the Queenston and Medina are the most notable and the Salina the least prominent. The Queenston shale is mostly red in colour and easily identified even if broken into small pieces or ground to a

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powder. The Salina (salt-bearing) formation contains green, grey and a little red shale interbedded with limestone and dolomite. The Huron shale is black and calcareous, and the Hamilton formation includes shale interbedded with limestone. The Lockport and Guelph dolomites occupy a belt immediately west of the Niagara Escarpment. The Onondaga and Delaware limestones of the Norfolk formation are pale brown or grey and contain many fossils and pieces of flint. Since the dolomite is also grey or pale brown the two are not easily distinguishable by sight when they

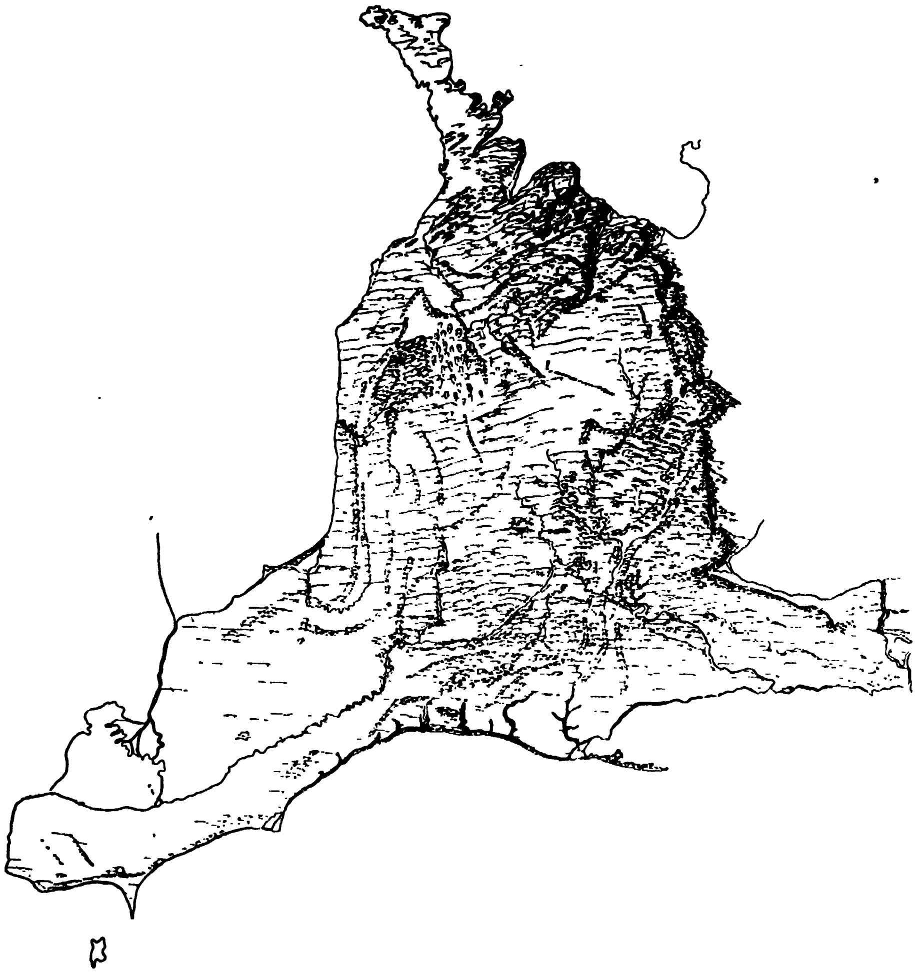

FIGURE 1. Physiographic diagram of Southwestern Ontario, giving a bird's-eye picture of the surface form.

appear as pebbles in the till. It will be noticed that in the Essex peninsula the younger strata have been worn away exposing the older limestones of the Norfolk formation.

The bedrocks in Southwestern Ontario lie in the form of a broad half-dome, the northeastern part of which has been removed. They slope upward from Lakes Erie and Huron to the brow of the Niagara Escarpment

at the rate of 20 or 30 feet per mile, while the warp of the strata is well-shown on the Niagara Escarpment. The cap rock rises from an altitude of about 650 feet above sea level along the south shore of Lake Ontario to over 1,700 feet a few miles south of Collingwood then slopes towards the north to less than 800 feet along the east side of the Bruce peninsula. In the Niagara peninsula the Onondaga limestone terminates in a second, low, northward-facing escarpment.

The Niagara Escarpment is the most conspicuous topographic form in peninsular Ontario. The cap rock is a massive dolomite, while the lower slopes are of shale. It was formed by the differential erosion of these two rocks. Here and there along the Georgian Bay the Manitoulin dolomite below the cap-rock extends out to form a shelf that terminates in a second bluff. The structure is illustrated by Figure 10. The area under study includes some level country below the escarpment along Lake Ontario and Georgian Bay.

Along the edge of the Niagara Escarpment a series of stream valleys have been cut into the rocks. The largest, now occupied by the Beaver River extends about 25 miles south to Flesherton from the shore of Georgian Bay. The Dundas valley, running west from the tip of Lake Ontario apparently extends for only 15 miles because it is filled with drift beyond. Other rock valleys partly filled with drift add to the ruggedness of this eastern borderline. Moreover they exerted a definite control over the movement of the glacier as it moulded the surface deposits into their present position and form.

SURFACE DEPOSITS

Depth to Bedrock

There were at least two and probably three glaciations in this region before the Wisconsin which laid down the upper drift. The older materials often come to light in stream cuts and in the shorecliffs of the Great Lakes. In comparison with Wisconsin materials they are bluish rather than brownish and more compacted. We have little information about the older tills and interglacial strata, but they at least affect the depth to bedrock.

The bedrock is at the surface or at no great depth along the top of the Niagara and Onondaga escarpments, and the depth of drift increases towards the southwest. In the extreme southwest, outcrops of limestone near the Detroit River and on Pelee Island are exceptions to this rule. In the counties bordering Lake Erie there are many gas and oil wells, and the driller's logs which note the depth to rock are published in the Summary Reports of the Geological Survey of Canada. One log, south of Chatham, reports 260 feet of overburden. In western Norfolk county all six of the records obtained show between 215 and 259 feet of unconsolidated material. Along the shore of Lake Huron, except north of Southampton, 100 feet to rock is about average. In the Kitchener vicinity the depth is indicated by figures of 178 and 194 feet a few miles west of that city. In the northern half of the area the drift is shallower than in these localities and the bedrock often is exposed in stream valleys at less than 100 feet below the level of the surrounding country.

Outline of Wisconsin Glaciation

From the standpoint of glacial geology the main points in the history of the recession of the last glacier have long since been established. The writings of Taylor, Leverett, Spencer, Goldthwaite, Coleman, Johnson, Stanley and Maclachlan are full of interest to anyone wishing to read about local glacial history. Of these the works of Mr. F. B. Taylor, an American who made most of his excursions into Canada at his own expense, are classical. More recently Mr. F. F. Morwick of the Ontario Agricultural

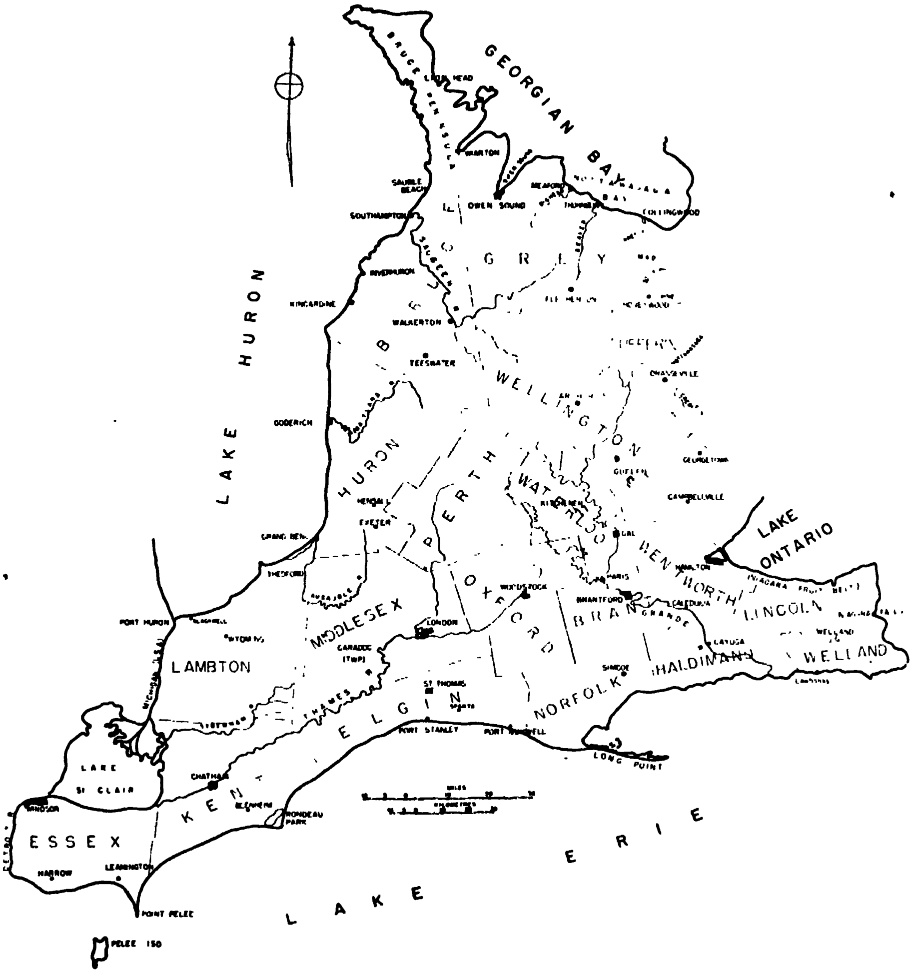

FIGURE 2. Key map showing landmarks mentioned in the text.

College, during the course of soil surveys, has accumulated a wealth of detail about glacial lake and glacial features in the southern part of this area which was made available to us.

With the information from all these sources as a background, the writers in their field work during the summers of 1940, 1941 and 1942 were able to fill in some of the gaps left by former investigators, so that fairly complete

and accurate maps of all the glacial features may now be drawn. We have on occasion differed with previous writings but as far as possible in this article controversy has been avoided.

The Wisconsin glacier covered all of Ontario including the highest parts of Grey and the Bruce Peninsula. Nowhere was any evidence found of a difference in soil age like that seen at the edge of the Wisconsin till sheet in southern Ohio. The promontory southwest of Collingwood undoubtedly diverted the flow of ice in two directions around the highland of Grey and Dufferin and this was the first land to be uncovered during the recession. The absence of an interlobate moraine on the central part of the upland is interpreted to mean that the ice sheet stagnated and melted off, while outside this plain the surface was moulded by two tongues of ice, one entering the Huron and the other the Erie basin. For a time they met head-on near London and as they withdrew minor readvances by either lobe created a series of parallel moraines to the north and south of that city. After uncovering nearly all the peninsula there was a general readvance and a great horseshoe-shaped moraine was built around the shoulder of the higher land. This system is composed of two main strands with additional minor strands in some places. From this position the glacier gradually receded with only one or two short interruptions until it was beyond the limits of the area.

From the time the lobes separated to unburden the land southwest of London the lower areas in the Huron and Erie basins were under water. During this time the St. Lawrence Valley was blocked with ice so that the lake basins filled to higher levels than at present before finding outlets. Four of these, one at Imlay, two near Ubly on The Thumb and a fourth and lowest at Grand Rapids carried the drainage across Michigan to the Mississippi. Further retreat of the glacier permitted the waters of the Huron Basin to drain eastward into the St. Lawrence system through two outlets. The first was by way of the Kawartha Lakes and the Trent River and the other through the Mattawa Valley from North Bay to the Ottawa River. As long as the St. Lawrence Valley was blocked with ice a higher, larger lake stood in the Ontario Basin with its outlet at Rome, N.Y. into the Mohawk Valley.

Each of these lakes formed beaches of gravel or sand or cut shorecliffs to mark their limits. Further evidence is to be seen in the delta sands occurring at the mouths of the rivers and in the stratified silts and clays farther out in the old lake plains.

Moraines

The centre-piece among glacial features of Southwestern Ontario is the Horseshoe moraine. This complex moraine system and the abandoned stream channels produced by contemporary drainage appear conspicuously on the moraine map (Figure 4). This map varies considerably from Taylor's maps and also distinguishes between moraines that were pushed into position by an advance of the glacier (till moraines) and those that were deposited by meltwater along a stationary or receding ice front (kame moraines). The former are mostly of boulder clay while the latter consist of roughly stratified sand, gravel or cobbles.

One can hardly fail to notice the similarity in the arrangment of kame moraines and spillways on the east and west sides of the central plain. The action of the Huron lobe on one hand resembled that of the eastern tongue on the other. And the drumlins around Teeswater balance the drumlins north of Guelph adding to the similarity.

The western limb of the Horseshoe moraine enters Michigan just south of Port Huron, where it is called the Port Huron moraine; on the eastern side the strands pass near Paris and Galt and were given these names by Taylor (16). Its character is not uniform throughout. From Walkerton

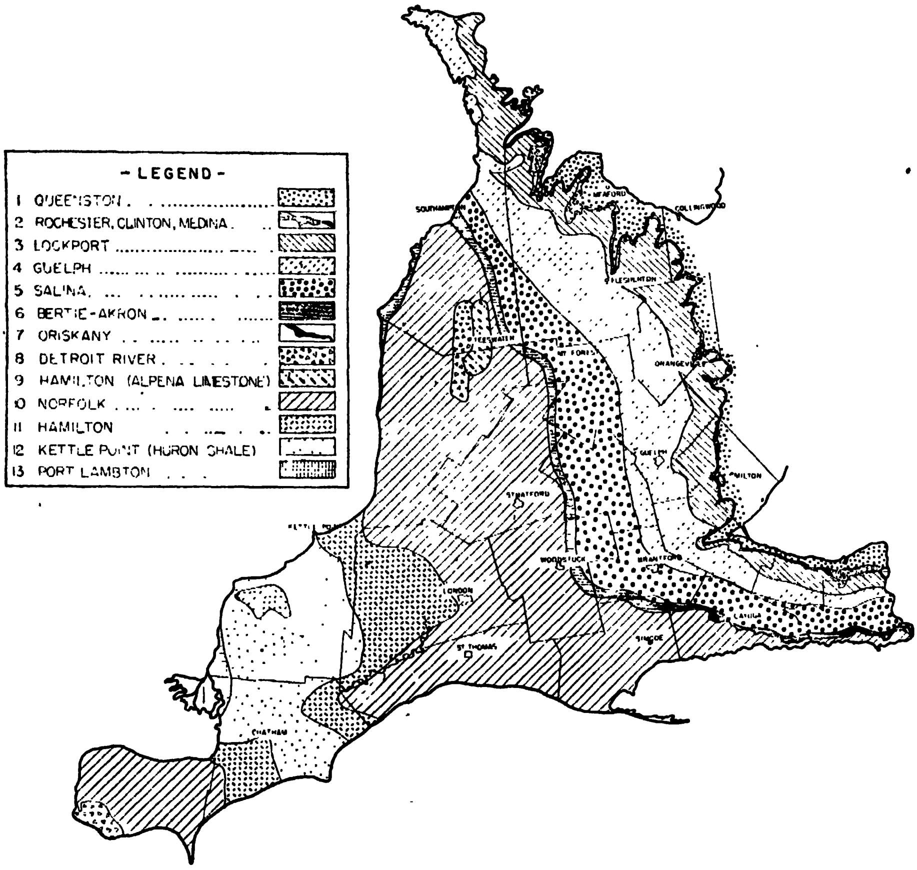

FIGURE 3. Bedrock map compiled from several maps of the Geological Survey of Canada.

up the slope to the Escarpment then southward as far as Brantford the strands are rugged and stony with occasional sandhills. On the Lake Huron slope they are less rugged and are composed of heavy boulder clay. The character of the material and the presence of stratified clays between these moraines and the Huron shore suggest that the glacier built the ridges by pushing up clay from previously deposited beds. The extremities of both limbs, south of Exeter and of Brantford, were built under the water of glacial Lake Whittlesey and therefore are much smoother than land-laid moraines. In fact the western limb is too faint to be seen west of Wyoming.

The moraines north and south of London are also of boulder clay, containing a high proportion of limestone from the Norfolk formation. Those around the western end of Lake Ontario are also clay ridges containing a good deal of red shale from the Queenston and Medina formations. The low clay moraines south of Chatham contain black shale from the Hamilton formation.

The kame moraines provide some of our roughest topography. As seen on Figure 4 their distribution is irregular, yet most of them are grouped in two belts before the Horseshoe moraine to the northwest and southeast

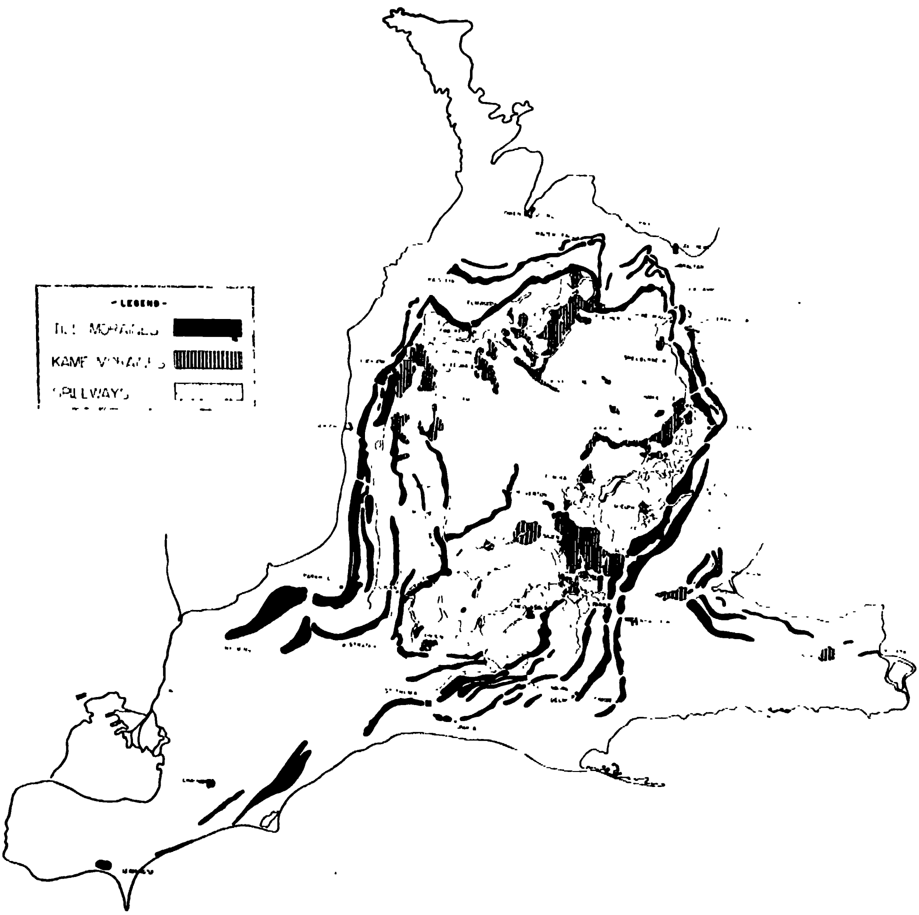

FIGURE 4. Map of moraines and spillways.

of the central plain. A favourite place for their formation is along the sides of valleys. They occur along the Niagara Escarpment, at the heads of the valleys which indent it, for instance at Flesherton west of Dundas and at Fonthill, and at these places the outwash sands which are invariably associated with kames are present in typical form.

The spillways that carried the drainage from the melting glacier downslope along its edge are common features of the landscape in Southwestern Ontario. When mapped as in Figure 4 they appear as a network in front

of the Horseshoe moraine and as strips along the side of the Niagara Escarpment. While the moraines stand above the surrounding plain the spillways, on the contrary, occupy depressions. These troughs are partly of their own making and are floored with beds of gravel or accumulations of muck. The gravel terraces are often at two or more levels, the lower ones being within the higher. The streams flowing in them are misfits, being far too small to have produced the broad channels to which they are confined. These points are illustrated by a block diagram, drawn to scale, of the spillway that runs southward past the village of Hillsburg. From this impressive size they grade to very small dimensions.

On the eastern side of the central plain the Thames, Grand and other rivers flow through glacial spillways. Near Honeywood a sandy basin of a few thousand acres marks the upper end of this set of spillways. The

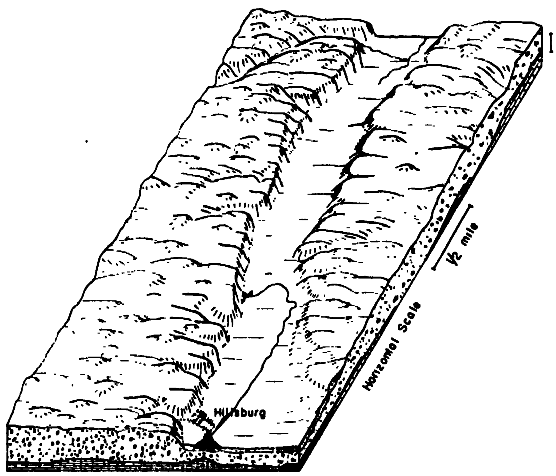

FIGURE 5. Block diagram of the glacial drainage channel at Hillsburg, Ont.

Grand meanders over gravel terraces, while the Thames runs within definite troughs worn in the till plain. On the western and northern sides of the upland the Ausable, Maitland and especially the Saugeen rivers are similarly confined, through part of their lengths, to the broad spillways floored with gravel, sand or muck. West of Walkerton, the Greenock swamp developed in a pocket of the spillway at the bend of the moraine. When the ice front stood near Teeswater, drainage flowed directly away from it, southward, and a good deal of outwash was laid down between the hills.

The last of the glacial streams in this area left their mark in a peculiar manner. Along the slopes of The Escarpment sand or gravel was deposited in spillways between the glacier and the hillside to the west in the form of terraces when the glacier withdrew. In the valleys of the Nottawasaga, Pine and Mad rivers these beds are very deep. Their flat-topped character

is preserved in part only; some sections have been cut through by gullies, while wind erosion has added to their mutilation. Incidentally, the sand removed was spread out again in glacial Lake Algonquin to form the sand flats around Camp Borden and Alliston. Most of the terraces are north of the Oak Ridges moraine of Central Ontario which abuts the Escarpment just south of Orangeville. South of this there are only a few trains of gravel such as that in the vicinity of Georgetown and just east of Campbellville.

The area covered by spillways is nearly as large as that occupied by moraines. The swampy portions are seldom cleared and are adapted to white cedar, while the deeper beds of sand or gravel have engendered some very good soil.

Till Plains

The till plains are definitely related to the sheet of boulder-clay or boulder loam spread over the surface by the Wisconsin ice sheet. It covered all the area except the few patches near the escarpments and on Pelee Island where the bedrock was swept clean. We have already seen that moraines and spillways, which were products of the recession, have modified or buried much of the ground moraine; and we will later point out the areas which received locustrine sands or clays to bury the till. First, however, let us deal with the unmodified parts of the ground moraine. Since they have generally smooth topography they may be called till plains.

The most interesting parts of the till plains are the drumlinized sections. Here the till was moulded into many oval hills with their long axes always aligned with the direction of movement of the ice sheet. Their distribution is shown by Figure 6. It will be seen that both the Huron and the Eastern lobes left drumlins although more of them were shaped by the former. A rough estimate of the number of drumlins in the whole area is 2,000, made up as follows: about 500 in Arran and adjacent townships west of Owen Sound; at least 1,000 in the rest of the large "field" in Grey and Bruce, about 400 in the Guelph area and 60 in the small group south of Caledonia. This is only half as many as are estimated to be in the central part of the province north of Lake Ontario. With the exception of the groups west of Owen Sound and in the Bighead Valley near Meaford the drumlins are more widely scattered than in Central Ontario.

The orientation of the drumlins is also shown in Figure 6. They fan out radially around the end of Lake Ontario, depicting the movement of an ice tongue in that basin. In the Walkerton vicinity a change of direction inside and outside of the Horseshoe moraine is evident, while west of Owen Sound there is a further reorientation. The positions of the drumlins and the moraines are the main items used in piecing together the history of a glacier's recession.

The drumlin symbols on the map are not drawn to scale. The majority of these hills are one-half to three-quarters of a mile in length and one-quarter to one-third of a mile wide. West of Owen Sound they are of the long, narrow type, while in the Bighead Valley near Meaford they are oval and very large.

Near Teeswater the flats between the drumlins are often floored with gravel or sand. This is stream gravel or outwash. North of Guelph there is a network of spillways running across the grain of the drumlin field. The drumlins south of Caledonia were submerged in a glacial lake after their formation and stratified clay was deposited between them. Some were completely buried, others have only their crests exposed while the clay encroaches upon the sides of them all. In parts of Arran township also drumlins and clay flats are associated.

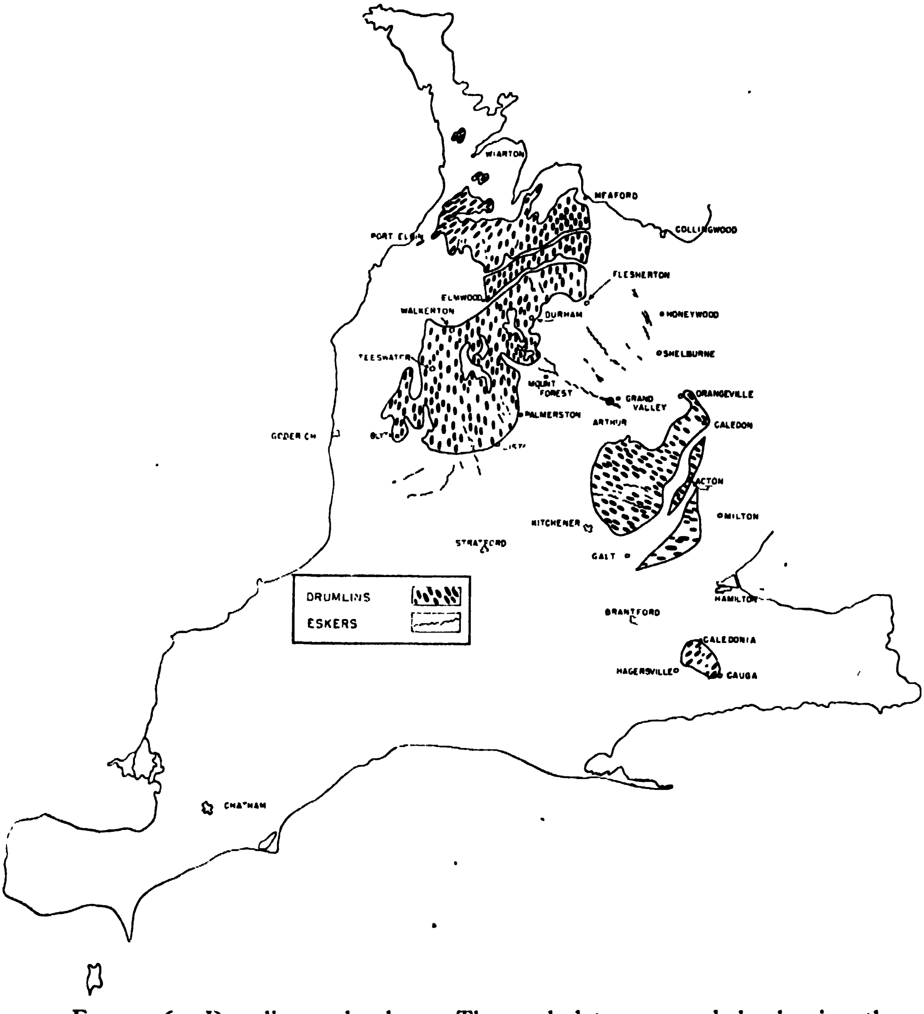

FIGURE 6. Drumlins and eskers. The oval dots are symbols showing the orientation of the drumlins, but they do not locate and outline them exactly.

Figure 6 shows eskers in addition to drumlins and it is apparent that they are frequently associated. Eskers are knobby ridges of sand or gravel and are closely related to kames. They may be considered to be chains of elongated kames superimposed upon the till sheet. They take a crooked course across the till plains, and are conspicuous on account of their topographic form and the coarse material of which they consist.

Between Mount Forest and Shelburne a series of eskers is situated. The one running from Mount Forest to Grand Valley was mentioned by Taylor in 1908 (15). These were formed under the influence of ice from the Huron basin. The longest of these ridges formed by the other ice lobe runs from College Hill at Guelph towards Elmira.

The undrumlinized parts of the till plains can be divided into several sections on the basis of depth to rock, topography, or the character of the till.

Along the brow of the Niagara Escarpment the till is frequently shallow or absent. It was swept off the prominence by the advancing glacier. In Welland and Haldimand counties there are similar shallow limestone plains scattered along the Onondaga escarpment, and small outcrops of limestone occur near Amherstburg and on Pelee Island. Excessive stoniness is also common where the till is scanty, which further reduces the value of the soil. Only a small proportion of this land is cultivated, nearly half is in rough pasture and the remainder is still in forest.

In the high, till plain northwest of Arthur the drift is not deep enough for drainage to become established. Its main drainage outlet is the Grand River and, as seen at Grand Valley, the deepening of its channel has been held up by a floor of dolomite. As a result of inhibited drainage, swamps are numerous and other wet land just as common. One is bound to remark here about the "willow flats" that characterize this plain The wet land that was cleared then relegated to permanent pasture has invariably produced a growth of dwarf willows.

Southwest of Arthur the drift is deeper, the topography more rolling and the willow flats not so numerous. However, drainage is still far from perfect. At Arthur the till is a sandy boulder clay consisting mostly of dolomite, and it gradually gets heavier until the brown clay till of the Huron slope is reached. South of Atwood, around the Ellice swamp north of Stratford, and southeast of Tavistock, three tracts having a layer of stratified clay and silt on the till are situated. This clay was probably deposited in shallow pondings during the retreat of glacier. In Oxford county at the southern part of the central plain the drift is deep, the topography quite rolling and the material in the upper till is a pale brown calcareous loam.

Below the Horseshoe moraine there are two types of clay till, one on the Lake Huron slope and the other below the "Blue Mountain" around the Georgian Bay. The first type is found in a narrow strip between the Horseshoe moraine and the beach of glacial Lake Warren, widening north of Kincardine beyond the reaches of Lake Warren. It is a pale brown calcareous clay containing comparatively few pebbles. Below this sheet of till, which averages about 6 feet in depth, it is not unusual to find a crumpled bed of stratified clay which was probably the main source of the clay in the till above.

Between Owen Sound and Nottawasaga Bay a shallow layer of red, shaly till is found on the shale at the base of the escarpment. In the Bighead and Beaver Valleys, near Meaford and Thornbury, the till is deeper and contains more limestone and hard silicious rocks from the north than the shallower till.

The till plains, altogether, cover about 3,800,000 acres, which is nearly 40% of the total area. This means that the till in over 60% of the area is modified or buried by glacial drainage channels, moraines, lake-laid sediments or peat. In fact, glacial and post-glacial lakes at seven main levels covered about four and one-quarter million acres of Southwestern Ontario.

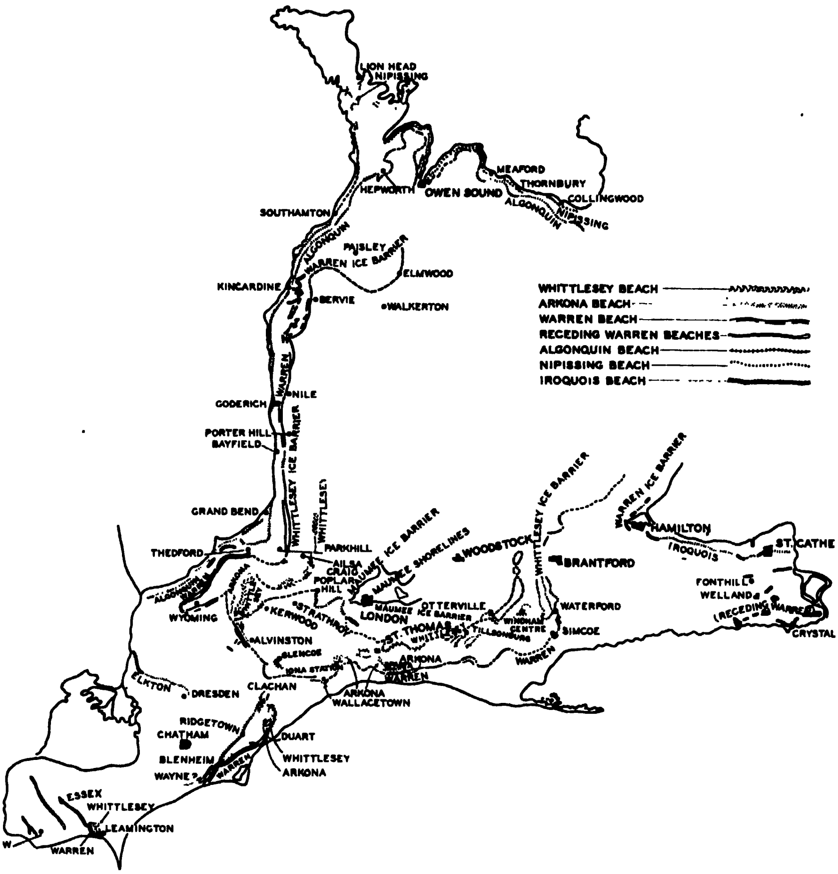

FIGURE 7. Map of shore features—beaches, bluffs and indistinct shorelines.

Glacial Lake Deposits

A map of shore features is given in Figure 7. It specifies the existence of a beach, shorecliff and boulder pavement or a featureless shoreline. In comparison with Leveretts map (8) there are added details and a few changes in the location of the shorelines. Some of these changes agree with MacLachlan who studied the levels of these beaches in considerable detail (9). On the other hand they more often concur with the unpublished maps of Mr. F. F. Morwick of the Ontario Agricultural College.

The first and highest of the glacial lakes in the Great Lakes basin is Lake Maumee, named after a watershed in northwestern Ohio. During the existence of this lake the Huron and Erie ice lobes met so as to cover all the land below London. North and east of that point, the two lobes separated, exposing the land between them. From the city of London eastward for 8 miles there are stratified sediments that must have settled in standing water. The airport at Crumlin is on interstratified sand and clay. In Ohio the Maumee beach is about 50 feet higher than the next one below it. This ponding at London is 100 feet above the next (Whittlesey) beach, about 925 as compared to 825 feet; its outlet was over the ice along the line of contact between the two lobes and it is suggested that it was a contemporary of Lake Maumee. It did not form any distinctive shore features, but the limits of the sediments are quite definite.

The next beach to be formed belonged to Lake Arkona, but since the water later rose again to a higher level and built the Whittlesey beach the latter will be discussed first. From Brantford to Exeter the Whittlesey beach or shorecliff marks the boundary between till plain and lake plain, if we except the small area east of London. The extremities of the beach meet the eastern and western limbs of the Horseshoe moraine at Brantford and Exeter proving that this moraine was built during the time of Lake Whittlesey. The beach itself is not as strong as the one below it, and in a few places where no gravel was available the location of the shoreline is indefinite. However, in Ontario this lake merits fame for its deltas; even though, peculiarly enough, the lack of good deltas in Michigan and Ohio is pointed out by Taylor. The Thames spread sand over Caradoc township west of London, and the border-ice stream, in front of the Paris and Galt moraines, debouched an immense quantity of sand into this lake southwest of Brantford covering most of Norfolk and adjacent parts of Elgin and Oxford counties. It is notable that no such large delta was formed at the mouth of the spillway in front of the western limb of the moraine, only a small one being present south of Exeter.

The highest water of Lake Arkona stood about 30 feet below the Whittlesey level and the lake built three beaches close together. However the Arkona beaches seldom appear as distinct ridges and the gravel is spread out as if by washing. From this and other evidence it is concluded that these beaches were formed before the advent of Lake Whittlesey and were submerged when the water rose to the Whittlesey level. Lesser beaches might have been dispersed beyond recognition when subjected to such wave action, but the Arkona gravel strand is heavier than those just above or below it. Between Arkona and Alvinston and on Ridgetown "island" as seen on Figure (7) it is at its best. Here it gives rise to strips of gravelly soil and furnishes road material from several large pits. South of St.Thomas and west of Sparta there are broad gravel ridges which are considered to belong to Arkona. The fact that the strand west of Sparta is partly buried by stratified silt proves that it was under water for a time. East of Sparta all traces of this beach are lost under the sands of the great delta, mentioned in the last paragraph.

Lake Warren left two beaches, the lower one lying 10 to 15 feet below the upper and never very far away from it. From the Niagara Escarpment north of Hamilton to the other ice barrier north of Kincardine this shoreline

extends for nearly 300 miles. To this may be added 50 miles of beaches around the island on which Ridgetown is situated and a smaller island at Leamington to get its total length. This does not include the Saugeen embayment where there are no beaches or bluffs to be found. Along the Huron slope it replaces the Whittlesey beach as the upper limit of lake plains. Most of the larger rivers of Southwestern Ontario were active during Warren time and each brought down sand and gravel to be debouched into the lake. The delta at the mouth of the Grand River merges with the Whittlesey delta so that is limits cannot be outlined. At the mouth of the Thames there is a huge spread of sand covering part of Middlesex, Elgin Kent and Lambton counties. The Saugeen's delta north of Walkerton covers about 50 square miles and smaller ones were laid down near Goderich and Bayfield by the Maitland and Bayfield rivers.

The most important beds of silt in the region are in the Warren plain on the fringes of the deltas. The largest tracts are found east of Brantford, in southern Elgin county and near Chatham and Blenheim. Stratified clays are found between Brantford and Lake Erie while deep beds of varved clay occur in the Saugeen embayment.

The last of the glacial lakes in the Huron and Ontario basins were named Algonquin and Iroquois respectively, after the Indian tribes that lived in these parts. They were both long-lived enough to develop splendid shore features. Between these and the Warren beach are some fragmentary beaches labelled "Receding Warren" on the map. The importance of these gravel bars is that they interrupt the clay plains of Welland and Essex counties. Perhaps the strip of shallow sand between the Warren beach and Lake Huron also belongs in this category even though typical beach ridges are wanting. The shoreline labelled Elkton marks the limits of the flat lands around Lake St. Clair and so has a special physiographic implication.

The Iroquois shoreline between Hamilton and the Niagara River runs near the base of the Niagara Escarpment. It built its most prominent gravel bar across the mouth of the Dundas Valley, where it now carries the highway and railroad entering Hamilton from the north, also the famous rock gardens. On the west side of Stony Creek is another strong gravel ridge on which some of the finest sweet cherry orchards are set. From the standpoint of sweet cherry production the extent of this beach is far too small. Between St. Catharines and Queenston there is a low bluff cut in boulder clay, and the boulder pavement associated has remained to trouble the farmers.

The deepest sands in the bed of Lake Iroquois occur in the vicinity of Grimsby. They are considered to be the product of wave action because no streams of any size entered this lake here, or anywhere between Hamilton and the Niagara River. Outside the Grimsby area the sand layer where present is seldom more than 2½ feet deep over the clay. Between Grimsby and Hamilton the red shale is at or near the surface in most of the plain giving rise to intractable clay soil.

The Algonquin shoreline from Sarnia to Collingwood is 240 miles long. As seen in Figure 7 it skirts the present shore except where it has been undercut by the present lake and obliterated. Some good gravel beaches were left by this lake; near Thornbury, Meaford and Southampton across

the valleys of the Beaver, Bighead and Saugeen rivers there are huge curving gravel bars, each with several distinct strands at different levels giving a stepped effect. South of Grand Bend a line of dunes has been blown up across the mouth of a lagoon and other dunes formed along the Algonquin shore are seen near Hepworth. Some prominent shorecliffs were also cut by Lake Algonquin, wave action being strong on the east side of the Huron basin. Between Kincardine and Southampton there is a nearly continuous bluff which in places is 100 feet in height. Invariably there is a boulder studded terrace at its base.

This lake is therefore responsible for the uninviting border of land along the shore of Lake Huron, which has spoiled so many attractive farm sites. It has also forced the engineers to build the Blue Water Highway so far from the shore that the beautiful greenish blue waters of the lake are out of sight.

The last of the extinct lakes is called Nipissing because its outlet was east of North Bay at the head of the lake that now bears this name. Around Georgian Bay its shorecliffs, boulder pavements or shingle beaches are fairly continuous; along Lake Huron many of them have been obliterated by the waves of the present lake. On the Bruce Peninsula, near Lion Head, part of Eastnor Township was low enough to be under Nipissing water and a level tract of silt and clay resulted, contrasting strongly with the unmantled rocks on either side and giving rise to the only farming section of note north of Wiarton.

Between Lowbanks on Lake Erie and the city of Welland is a low-lying, flat tract that includes the Humberstone Peat Bog. The surface is less than 10 feet above the present level of Lake Erie and apparently it was covered by the lake at an earlier period in its history. The lowering of Lake Erie sufficiently to uncover this plain is thought to be due to the deepening of the outlet at Fort Erie. A distinct shore terrace is to be seen at Lowbanks but elsewhere the margin is vaguely defined. Around the deeper parts of the bog there are patches of shallow muck in places overlying marl; and beds of calcareous sand silt or clay.

Another tract with topography "flat as a floor" borders Lake St. Clair. Between Dresden and the St. Clair River its limits are marked by a faint but continuous shoreline near the 600 foot contour relating it to a former lake in the St. Clair basin. The shoreline is also found in Michigan and was called Elkton by Leverett (7). Within this tract, as in the Humberstone area the beds are often highly calcareous, and soil profile development is feeble indicating that the sediments are of recent origin. Drainage has been established by means of municipal ditches which are now an integral part of the landscape.

North of Harrow, as shown on Figure 8, there is another level tract at a slightly higher level. The beds are of very fine clay containing less lime than those just described.

Some parts of the lake plains have very little stratified material over the till sheet. These parts may be called bevelled till plains, the bevelling being due to the lowering of the knolls by wave action and the building up

of the depressions with clay. The distribution of bevelled till is shown on Figure 8. In Essex and Lambton counties the exposures, with few exceptions, show boulder clay. The water-laid layer on the surface, if present, is weathered so that the stratifications are no longer visible. However, in the Niagara peninsula and on the Huron slope the till is not very distinctive, being merely reworked clay from stratified beds below. From the standpoint of soils, therefore, this material need not be separated from lacustrine clays.

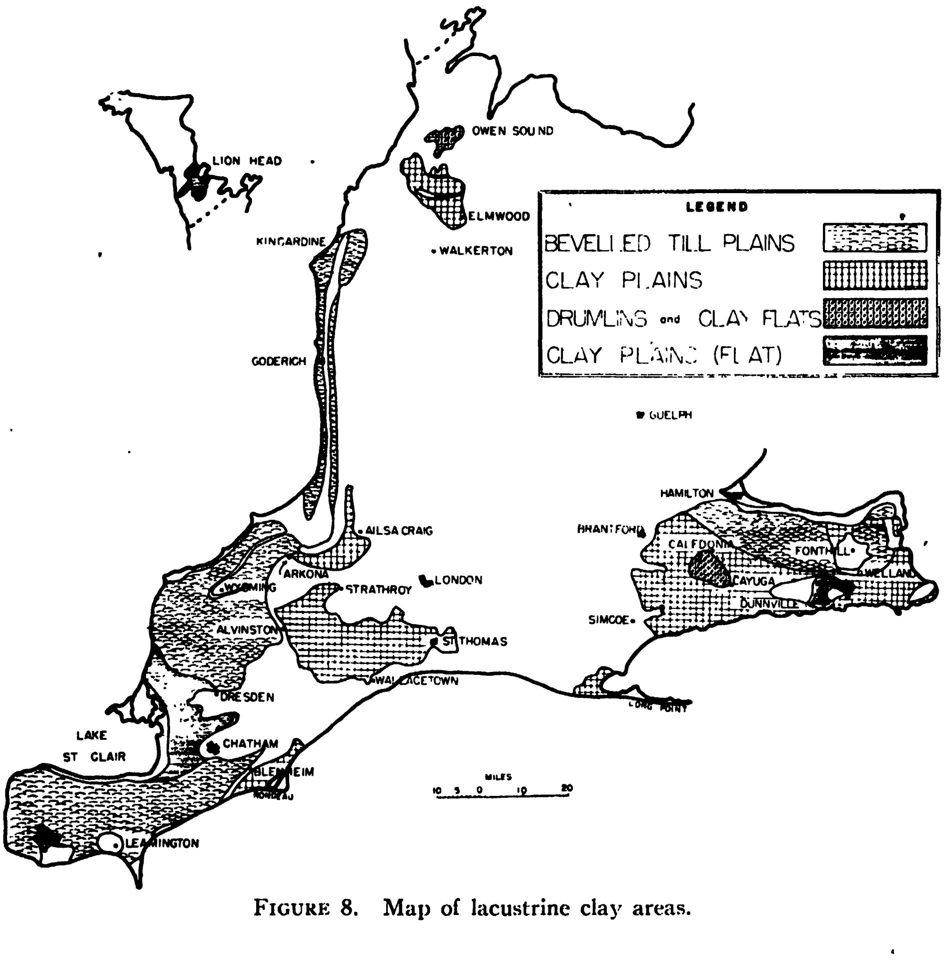

FIGURE 8. Map of lacustrine clay areas.

RECENT DEPOSITS

Shoreline Features

Peat or muck, marl, blowsand, alluvium of existing rivers and the shore features of the present lakes are the most recent surface deposits or forms. The south shore of Georgian Bay is littered with boulders, except just east of Meaford where a bluff is cut in the shale and in the few spots where sandy beaches occur. The Georgian Bay side of the Bruce Peninsula terminates in sheer rock cliffs in direct contrast to the strand line on the Lake Huron side where the rocks gradually dip below the lake. On Lake Huron there are several good sand beaches between Sauble Beach and Grand Bend

although shorecliffs and bouldery beaches are much more in evidence. The bluffs reach a height of 100 feet near Goderich. At Kettle Point, Clark Point, Inverhuron and other places the bedrock is exposed.

The Lake Erie shore is famous for its three sand spits at Point Pelee, Rondeau Park and Long Point. They separate three concave segments of shore. At Port Stanley, in the centre of the biggest "bite" the bluffs are 125 feet high. Some idea of the structure may be obtained from Figure 1. It is apparent that the shoreline has been eroded by wave action and it is interesting to speculate on the width to which the lake has encroached upon the land at this point. If a crow flew from Long Point to Rondeau Park, it would pass about 10 miles from Port Stanley. A straight line projected along the grade of the plain which borders the lake would drop between 10 and 15 feet per mile from the bluff at Port Stanley to meet the water of lake about 10 miles from the shore. According to the municipal maps and records at Port Stanley the bluff is receding nearly three and one-half feet a year. Assuming that Lake Erie has existed for 15,000 years it would at this rate have worn back the bluffs for about 10 miles. For these reasons we think that the shore was originally about 10 miles to the south of its present position at Port Stanley.

East of Port Dover the rock is often exposed and the bluffs are lower than they are farther west. The shore of Lake Ontario is similar, having low shorecliffs cut in boulder clay or shale with beaches built across the mouths of lagoons, as at Port Dalhousie and Jordan Harbour. Across the mouth of Burlington Bay is a well-known barrier beach called the Burlington Beach.

On the shores of Lake Huron and Erie there are outstanding lines of sand dunes at several locations. The three sand spits of Lake Erie each have some dunes. West of Crystal Beach for 12 miles they are extensively developed. Near Port Burwell a huge dune called the Houghton Sandhills illustrates well the action of shifting sand as it buries the trees and fences and spoils the land for agriculture. On Lake Huron the live dunes are best developed between Grand Bend and Kettle Point, while they are also found at Inverhuron and Sauble Beach.

Blowsand

In addition to the dunes on the lake shores, blowsand is frequently found in the sandy areas throughout the region. Fixed dunes along the ancient shorelines may be rejuvenated, as many have been in the counties bordering Lake Erie. Blowsand is common throughout the delta sands. The kame moraines are subject to blowing if stripped of protective cover, and the sandy terraces along the Niagara Escarpment north of Orangeville are not always stable in the face of wind action.

Alluvium

As a rule, the rivers of Southwestern Ontario have only gentle grades, and they meander over flood plains between bluffs after the fashion of slow-flowing streams. In springtime, or other times of flood, the bottom lands receive a dressing of alluvium preventing the development of normal soils. The alluvium may be of silt, sand or gravel. It is a mixture of top-soil and raw subsoil so that it contains some humus. In this region it

invariably contains plenty of limestone or dolomite. Most of this material comes from bluffs along the river or out of gullies in the nearby slopes. The establishment of a cover of trees or sod to protect these sites is a matter that has recently come into great prominence.

Two special cases should be mentioned when discussing alluvium, that of the clay deposited on the banks of the Thames in Kent county and the silt and sand of the St. Clair delta. In the level country below Thamesville periodic floods have produced faint levees in which the clay is pale reddish brown, distinguishing it from the brownish grey clay of that area. The material in the "birds-foot" delta at the mouth of the St. Clair River is little weathered and is classed with alluvium rather than delta sands. It is highly calcareous and contains considerable organic matter.

Along Lakes Erie and Huron where there are high bluffs to provide the fall a series of short rapid streams have developed, and they have cut abrupt V-shaped valleys which dissect the plains adjoining these lakes. Similar valleys are cut by the small streams which flow over the Niagara escarpment.

Peat and Muck

The poorly drained basins in which peat or muck has accumulated are numerous in the high plain between Arthur and Singhampton. Because of the gentle grades and the presence of solid rock at no great depth, drainage channels are poorly developed. Many small bogs occur in the kettles on the moraines, and in the abandoned glacial spillways are long wet troughs in which cedar swamps are found. On the slopes outside the upland, swamps are conspicuously scarce, as they are on the southerly slope north of Lake Ontario. This is because of deeper drift, a little steeper grade, or the planing effect of the glacial lakes on the lowlands, all of which help the drainage. However, a large bog lies in the depression below the Onondaga Escarpment south of Welland and another one, called the Greenock Swamp, has developed west of Walkerton in a pocket where drainage was impeded by the Horseshoe moraine. On the South shore of Lake Huron are two valuable marshes in lagoons near Thedford and Blackwell, and a similar tract of muck called the Erieau Marsh is located behind the sand spit at Rondeau.

PHYSIOGRAPHIC DIVISION

In the foregoing paragraphs the various landforms of Southwestern Ontario have been segregated and described. For the purpose of giving a simplified picture of the landscape, seven physiographic types have been set up and mapped in Figure 9.

1. *Escarpment*

The face of the Niagara Escarpment exhibits a terrain not found elsewhere in Ontario. The bluffs along the brow are of dolomite and the slopes below carved in red shale. It extends for well over 200 miles from the Niagara River to Owen Sound. North of Owen Sound the Escarpment is present at or near the Georgian Bay shore, but the strip to be mapped is so narrow that it has not been shown. Surrounded by a glaciated landscape this pre-glacial land form is quite distinctive. The long uniform

slope presents a great contrast with the knobby irregular hills found on the moraines. The stream valleys which indent it also resemble those of unglaciated territory.

Between Honeywood and Orangeville there is a stretch where the escarpment is buried by glacial drift piled against it from the east. South of Orangeville, in Caledon township, only the upper part remains uncovered.

The steepness of the slope has prevented clearing for agriculture in some places, particularly in the vicinity of Georgian Bay. Where the land is cleared the farmers usually face problems of soil erosion and droughtiness that are common in non-glaciated regions.

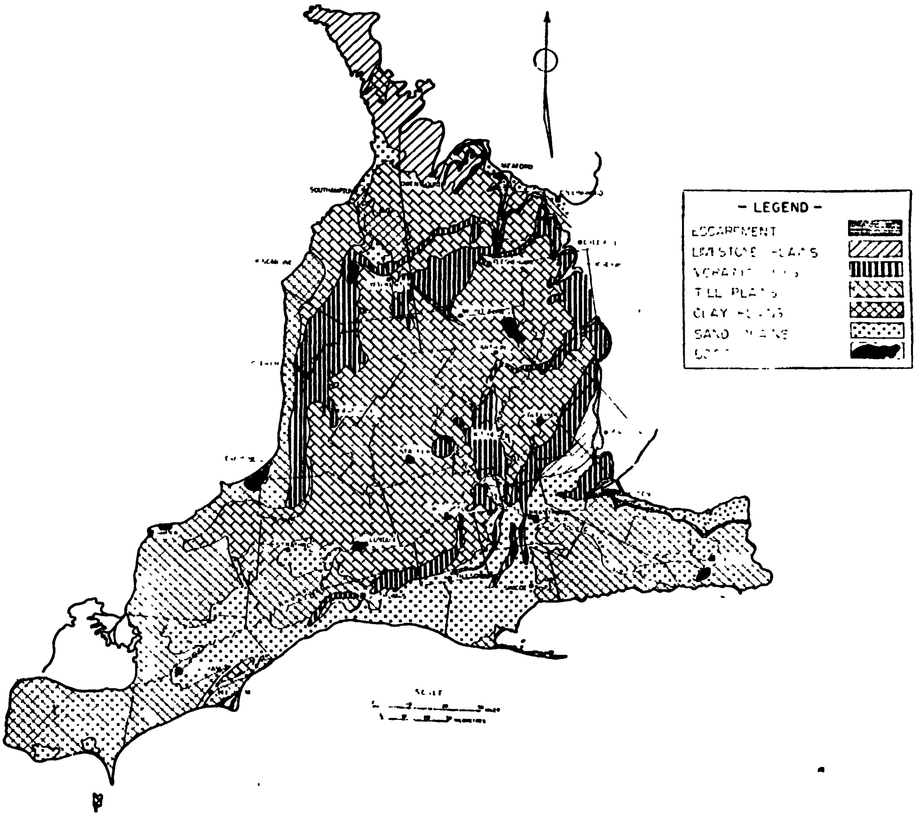

FIGURE 9. Physiographic divisions of Southwestern Ontario.

2. *Limestone Plains*

In many places along the brow of the Niagara and Onondaga escarpments the limestones are swept clear, or nearly clear of overburden. There are approximately one-half million acres of limestone plains, most of which are in the Bruce peninsula. The surface is usually sprinkled with blocks of dolomite or other stones. There are also numerous small swamps.

There is no need to stress the limitations imposed on farming by shallow rocky soil interrupted frequently by swamps. The poorer tracts can be left to produce maples and other hardwoods, while much of the cleared land will be pastured. Very little is fit for intensive cultivation.

3. *Morainic Hills*

Morainic hills characterize a horseshoe-shaped belt of one and one-half million acres that surrounds a high, central plain and separates it from the lower plains flanking the lakes. Some of the smoother moraines are excluded from this category, while on the other hand the drainage channels associated with the moraines are unavoidably included. The clay ridges on the Huron slope are relatively smooth moraines, while the kame moraines provide some of the roughest topography. For the most part the material in this drift comes largely from the underlying bedrock. Stoniness is general.

The knob and kettle topography, where most pronounced, imposes a severe limitation on agriculture, because it results in small irregular fields and hillsides that are subject to erosion. On the smoother, less stony ridges a good many fine stock farms have developed.

4. *Till Plains*

More than one-third, or 3,840,000 acres of this peninsular part of Ontario consists of till plains. The broad tract lying inside the moraines on the long slope from the height of land to the vicinity of London is not drumlinized. It is an undulating plain, beset with swamps in the higher part, with only an occasional esker to break the monotonous topography. Around Guelph and Teeswater there are drumlin fields often with gravel and sand in the hollows between the drumlins. North of the Horseshoe moraine in Grey and Bruce counties, the till plain is drumlinized except in a few places near Georgian Bay and Lake Huron. Some of the smoother clay moraines south of Lake Huron are also mapped as till plains.

Some details as to the materials comprising the drift in various sections are summarized in Table I.

Two or three general conclusions about the composition of the till of this area can be stated. Although it is not so high in lime as the till in much of central Ontario (10) it invariably contains carbonates, usually in abundance. The bulk of the material comes from the underlying rocks, but there are notable exceptions to this rule. The high clay content of the till in a broad belt bordering Lake Huron and Lake Erie is also worth mentioning because Wisconsin till is commonly more sandy (3).

Many types of soil are found within the till plains, differing in topography, drainage, texture and the composition of their parent materials. In fact some of the poorest and some of the best land in the area is represented.

5. *Clay Plains*

The clay plains are represented by the squares on Figure 9, and they occupy the lowlands bordering the lakes. They are estimated to have an area of 2,750,000 acres although this includes many small tracts with sand on the surface. None of this territory has much relief and some of it is flat. Between Lake Ontario and the Grand River there is rolling topography, while the silty flats around Lake St. Clair, southwest of Welland and near Lion Head represent the other extreme. Deep beds of stratified clay occur north of Walkerton, south of Brantford and in Middlesex county.

East of Brantford, south of St. Thomas and Blenheim and near Chatham good beds of silt are found. Much of the plain in Essex, Lambton and along Lake Huron has only a shallow deposit of clay so that much of the soil is developed on the till.

TABLE 1.—TILLS OF SOUTHWESTERN ONTARIO

Name	Location	Composition
Vinemount	In a belt 1–5 miles wide along the brow of the Niagara Escarpment.	Red shale and sandstone from the Queenston and Medina formations mixed with Lockport dolomite. Usually stony.
Dundalk	In the high plain northeast of Arthur.	Covering on bedrock is rather shallow. Till is a sandy clay consisting mostly of local dolomite.
Milverton	In the plain southwest of Arthur.	Clay content increases towards the southwest. There is not a belt of shaly till over the Salina formation, as might be expected. Material is all highly calcareous due chiefly to material from the Guelph and Norfolk formations.
Oxford	In Oxford County.	Calcareous, pale brown, loamy till.
Eramosa	In drumlin field between Guelph and Caledon.	Stony loam, mostly of local dolomite.
Teeswater	In drumlin field south of Walkerton in southern Bruce and northern Huron.	Stony loam, mostly of local limestone.
Huron	In a strip on the Lake Huron slope between Goderich and Southampton.	Brown, calcareous, heavy clay till; much of the material reworked from previously-deposited beds of stratified clay.
Grey	In the large drumlinized belt lying north of the Horseshoe moraine in Grey and Bruce.	Stony loam characterized by dolomite, except in the Bighead Valley where till is like that in the Beaver Valley.
Beaver Valley	In the Beaver and Bighead Valleys.	Mixture of Queenston and Medina shale and sandstone with limestone and siliceous rock from the north.
Cape Rich	In a belt bordering Georgian Bay between Owen Sound and Thornbury.	Shallow till, consisting largely of red shale from the underlying rock.
Essex	In Essex County, where till appears at the surface.	Has highest content of siliceous rock of any till in Southwestern Ontario. Is a drab calcareous clay loam.
Lambton	Lambton County.	Drab, calcareous clay containing some shale and pebbles of flint.
Ridgetown	On the Ridgetown-Blenheim moraine.	Grey, shaly clay.

6. *Sand Plains*

The sands are in scattered locations. The most important tracts, shown in Figure 9, cover one and one-half million acres or about the same area as the moraines. By far the most extensive tract borders on Lake Erie in Norfolk, Elgin, Kent and adjacent counties. These are delta sands deposited in glacial Lakes Whittlesey and Warren and they occupy well over a million acres. The Thames River delta in Lake Whittlesey, known as the Caradoc Sands occupies 82,000 acres, while the Saugeen delta in Lake Warren adds another 24,000 acres. The sand west of Welland was brought there by the Grand River, but the smaller tract lying north of

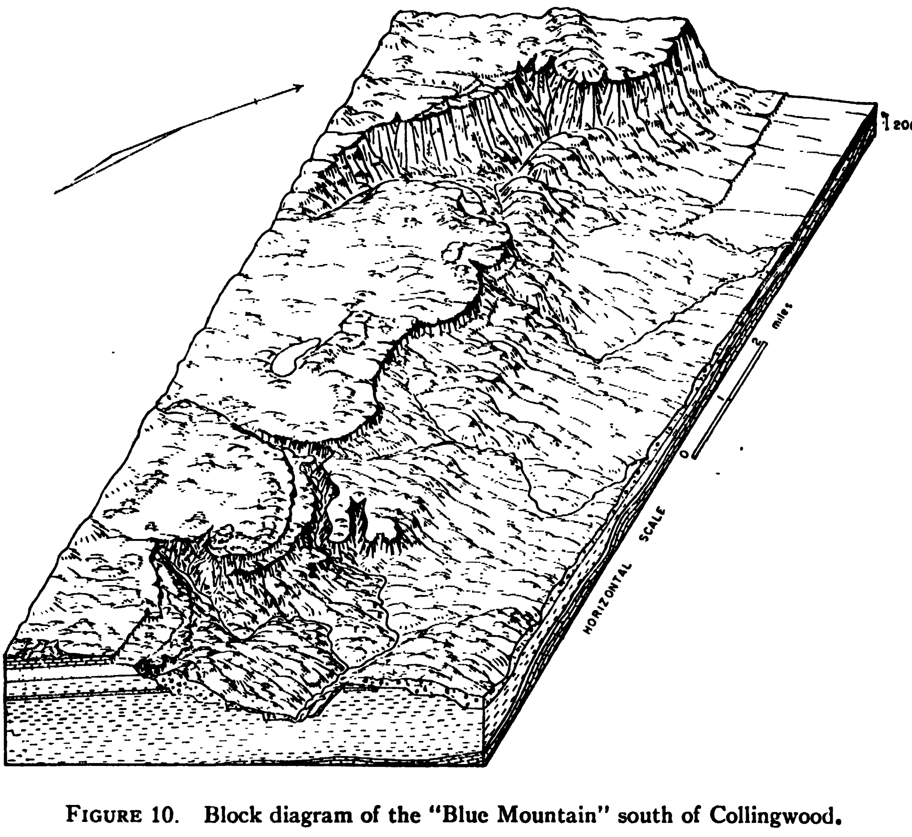

FIGURE 10. Block diagram of the "Blue Mountain" south of Collingwood.

this city is thought to be glacio-fluvial in origin. Similar outwash sand is found around Honeywood. In the Niagara Fruit Belt the sands are usually shallow over the clay and have a reddish colour due to Queenston shale. The patches between Meaford and Collingwood and near Leamington and Harrow are small but nevertheless important for special crops, principally apples along the Georgian Bay and early truck crops in the Leamington district. In fact the incidence of sand plains have with few exceptions resulted in the culture of special crops. Finally, it is worth noting that sand plains usually provide plenty of well water, which is not always the case on a clay plain.

7. *Marshes and Bogs*

In this region swamps and bogs are most frequent in the high central plain. The Luther bog is the largest, with an area of over 20 square miles. Some peat moss was mined from this deposit but the venture has been discontinued. However, only a small proportion of this bog is of sphagnum peat; most of it supports trees and contains more highly decomposed material. Lesser swamps of all sizes serve merely to break the continuity of the farmland on this plateau, and to serve as catch basins for water.

Outside the central plain, swamps are relatively scarce, but the important ones can be pointed out. The Humberstone bog is about half the size of the Luther swamp and lies in a depression north of the Onondaga escarpment. It contains a good deal of sphagnum peat. In Greenock township a big swamp of over 15 square miles has formed just inside the bend of the Horseshoe moraine. It contains shallow, more highly decomposed deposits, similar to those found on the fringes of the two bogs just mentioned. Near Thedford and Blackwell on the southern shore of Lake Huron, are two marshes in lagoons behind sandy barrier beaches. They contain muck, in places underlain by marl. Both marshes have been drained and reclaimed for intensive farming. Like the Erieau marsh south of Blenheim they are used to produce such crops as celery and onions.

SUMMARY

Southwestern Ontario is an elephant-shaped peninsula of slightly over ten million acres lying between the Great Lakes and the Niagara Escarpment. The build of this area and the major land forms are shown pictorially by means of a physiographic map.

This is a glaciated region and, with the exception of the escarpments which are due to differential erosion of the bedrocks, most of the surface features are the result of glacial action. The centre-piece among glacial features is a horseshoe-shaped moraine around the high land. A sketch map shows this moraine system together with the other till moraines and the kame moraines in considerable detail. It also traces the glacial drainage channels which were formed when the ice sheet was melting and receding from the area.

The continental glacier laid down a sheet of unassorted materials over all the area, except in those places along the brow of the Niagara and Onondaga escarpments where it swept the bedrock bare. In some sections it moulded the till into drumlins, the distribution and orientation of which are shown in a second sketch map. The eskers are also shown on this map.

As the glacier receded from Southwestern Ontario a series of ice-dammed lakes at seven main levels, temporarily inundated the lowlands. The abandoned shorelines of these glacial lakes, that is, the beach ridges or shorecliffs and boulder terraces, are mapped in another figure. This is a more detailed map of shorelines than any formerly published. It is useful in discussing the extensive sandy deltas, which are associated. When dealing with the water-laid clays a supplementary sketch map that separates the shallow deposits from the deeper beds and outlines the flat tracts is given.

The shorelines of the Great Lakes which are on three sides of peninsular Ontario are described briefly. Bold shorecliffs and boulder terraces are common to Lake Huron and Georgian Bay. Some special attention is given to the scalloped shoreline of Lake Erie.

The depth of the drift within the area increases towards the southwest. Fortunately some data on the depth to bedrock are available for the southwestern section, since copies of the logs kept by the gas and oil well-drillers are published. Between Point Pelee and Long Point the drift north of Lake Erie is mostly between 150 and 250 feet in thickness.

The composition of the surface materials directly affects soil type and is therefore discussed. Generally, the bulk of the material in the glacial till came from the underlying rocks, although the shale from the Salina formation has no appreciable influence on the till between Brantford and Southampton. Along the boundaries of the formations there is a mixture caused by "glacial drag" off the formation lying to the north or east. In Essex county an unusually high content of silicious rock from the Canadian Shield is found. Much of the lacustrine sand and clay is imported from higher lands, nevertheless, the influence of the bedrock is often manifest.

In post-glacial times beds of peat and muck have accumulated in various shallow depressions. In some instances also deposits of marl are found.

The complex mosaic of surface features has been generalized into seven physiographic types, including the Escarpment, Limestone Plains, Morainic Hills, Till Plains, Clay Plains, Sand Plains, Marshes and Bogs, which have been mapped in Figure 9 and brief descriptions of which are given.

In this account of land forms and geological materials, occasional mention is made of the soils and related agriculture. Much more remains to be done in order to achieve complete adjustment between crops and environment. Indeed this work is only the first step in the study of the use of land.

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VARIETAL SUSCEPTIBILITY TO KERNEL SMUDGE IN WHEAT[1]

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Kernel smudge or "black point" is a disease of the kernel in wheat, barley and rye. In wheat, it is characterized by a light or dark brown discoloration caused by fungi in any part of the grain, and more particularly in the region of the embryo. The fungi chiefly associated in Western Canada with this condition are species of *Alternaria* and *Helminthosporium sativum* P.K. & B. (7). Macroscopically, the *Alternaria* type of kernel smudge is difficult to distinguish from the *Helminthosporium* type. The former, however, does not affect to any appreciable extent the germinability of the affected seeds, the emergence of seedlings, intensity of seedling blight, or yield of the subsequent crop; whereas the latter usually reduces germination, seedling emergence, and yield, and increases the amount of seedling blight and root rot. Both types of the disease, however, discolour the grain, lower the commercial grade, and reduce the value of a wheat crop.

Harris and Sibbitt (6) studied the effect of "black point" upon the quality of durum wheat and found that the presence of heavily damaged kernels in the grain adversely affected the quality of processed durum wheat (semolina and macaroni). The chief effects observed were the occurrence of many black specks in the semolina, and an appreciable impairment of the colour of the macaroni. As these workers have pointed out, millers of durum wheat find it difficult to effect a clean separation of the dark specks in the milling process and therefore avoid purchasing lots of durum wheat that are affected with kernel smudge.

Hard red spring wheat affected with kernel smudge produces a greyish coloured bread and is of inferior quality for milling purposes. Such wheat is usually degraded according to the number of kernels affected and the intensity of kernel infection. Under Canadian Grain Standards, for instance, the presence of more than 5% of smudged kernels in spring wheat lowers the commercial grade from No. 1 Northern to No. 2 Northern. If more than 10% of the kernels is discoloured the grade is lowered from No. 2 to No. 3 Northern. The maximum amount of black-pointed kernels allowed in No. 3 Northern is 15%.

Bolley (1), Dastur (2), and others observed that wheat varieties differ markedly in their susceptibility to certain types of seed discoloration. Evans (3) and Weniger (11) reported that varieties of wheat belonging to the *Triticum durum* group were more susceptible to seed discoloration than were varieties of the *T. vulgare* group. Machacek and Greaney (7) examined a number of wheat varieties, grown at Winnipeg, Manitoba, from 1929 to 1935, and found that *durum* wheat varieties were more susceptible to

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kernel smudge than were the *vulgare* varieties. In a study of the reaction to this disease of several pure lines of a number of *durum* × *vulgare* crosses, Peterson[3] observed that although the susceptibility of the *durum* parent was carried over to most of the lines, a few lines showed a high degree of resistance to kernel smudge.

The incidence of kernel smudge in Western Canada varies greatly from season to season, and from district to district. Broadly speaking, it is always considerably higher in Manitoba than in Saskatchewan, and higher in Saskatchewan than in Alberta. In certain years, wheat losses from this disease, owing to the lowering of the commercial grade, reach appreciable proportions, particularly in Manitoba. Of 1000 cars each of durum and hard red spring wheat from different districts in Manitoba that were inspected at Winnipeg in 1940, 14.0 and 7.6%, respectively, contained noticeable amounts of kernel smudge, a large proportion of which was degraded for "black point".

Studies to determine the relative susceptibility of wheat varieties to kernel smudge were continued at Winnipeg in the years 1935–42, inclusive. During this period, certain standard varieties and new productions of durum and spring wheat were grown at several stations in Western Canada and their reactions to kernel smudge determined. In addition, during the 5 years 1938–42, plating tests were made of a large number of seed samples of wheat from different farms in Manitoba to determine the relative resistance of certain spring wheat varieties to internal kernel infection by *Alternaria* spp. and *Helminthosporium sativum*, the fungi chiefly associated with wheat seed discolorations in Western Canada. An account of these field studies and plating tests is given in this paper. A preliminary report on the subject has already been made (5).

EXPERIMENTAL RESULTS

Relative Susceptibility of Wheat Varieties to Kernel Smudge

In this investigation, the percentage of discoloured kernels in the threshed grain was the criterion used to compare the susceptibility of wheat varieties to kernel smudge. At least three 100-kernel lots were selected at random from the grain sample of each variety, and the number of smudged kernels in each lot was counted. The average of these counts gave the percentage of kernel smudge for that variety. In passing, it should be mentioned that a statistical study of different sampling and counting methods revealed that the precision of a kernel smudge count was not increased when more than three 100-kernel lots from each grain sample was used. All examinations of grain samples for kernel smudge were made with the unaided eye, under uniform, artificial light conditions, the examination of any given varietal test being made by one investigator. Thus, the disease data were obtained by uniform procedure, and are believed to give an accurate measure of varietal susceptibility to kernel smudge.

During the 7 years 1929–35, and in 1938, 1939, and 1940, a number of varieties belonging to each of the wheat groups *Triticum durum* and *T. vulgare* were tested for their reactions to kernel smudge. The varieties studied from 1929 to 1935 were grown at Winnipeg, Manitoba, while those

[3] Unpublished data of Dr. R. F. Peterson, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.

tested in 1938, 1939, and 1940 were grown at different stations, 3 in Manitoba and 2 in Saskatchewan. A summary of the kernel smudge data obtained is given in Tables 1 and 2.

TABLE 1.—PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF 3 DURUM AND 3 HARD RED SPRING WHEAT VARIETIES GROWN AT WINNIPEG, MANITOBA, IN THE 7 YEARS 1929–35

Variety	1929	1930	1931	1932	1933	1934	1935	Average (1929–35)
	%	%	%	%	%	%	%	%
Triticum durum								
Pentad	0.8	16.8	21.7	37.3	40.7	63.7	93.6	39.2
Acme	1.3	22.2	11.0	42.8	30.8	69.0	65.3	34.6
Mindum	2.6	11.5	15.7	33.4	39.3	24.2	55.0	26.0
Average	1.6	16.8	16.1	37.8	36.9	51.6	71.3	33.2
Triticum vulgare								
Marquis	0.4	4.1	2.6	3.6	0.7	9.3	10.8	4.5
Ceres	0.0	1.5	0.0	1.8	1.8	6.0	5.3	2.3
Reward	0.0	2.3	0.2	2.6	0.7	5.1	4.0	2.1
Average	0.1	2.6	0.9	2.7	1.1	6.8	6.7	3.0

TABLE 2.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE GRAIN SAMPLES OF 7 DURUM AND 7 HARD RED SPRING WHEAT VARIETIES GROWN AT STATIONS IN MANITOBA AND SASKATCHEWAN IN 1938, 1939, AND 1940

Variety[1]	R.L. No.[2]	1938	1939	1940	Average (1938–40)
		Number of test stations[3]			
		3	5	5	
		%	%	%	%
Triticum durum					
Iumillo × Mindum	1317	26.5	2.7	9.1	12.8
Iumillo × Mindum	1183	24.5	1.2	9.6	11.8
Mindum × Pentad	1245	17.3	0.7	1.9	6.6
Kubanka	1302	12.3	1.1	5.0	6.1
Pelissier	1303	11.1	1.2	4.5	5.6
Arnautka	570	8.2	1.3	4.0	4.5
Mindum	1344	9.2	1.0	2.5	4.2
Average	—	15.6	1.3	5.2	7.4
Triticum vulgare					
Apex	309	7.6	0.6	7.1	5.1
Thatcher	501	6.0	0.4	4.0	3.5
Renown	131	4.2	0.0	0.4	1.5
Marquis	1	0.0	0.0	2.6	0.8
Regent	135	2.2	0.0	0.4	0.8
Red Bobs	1827	1.2	0.0	1.0	0.7
Garnet	5	0.0	0.0	0.0	0.0
Average	—	3.0	0.1	2.2	1.8

[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Rust Laboratory Number, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.
[3] The varieties were grown at 3 stations in Manitoba in 1938, and at 3 in Manitoba and 2 in Saskatchewan in 1939 and 1940.

It is evident from the data in Tables 1 and 2 that wheat varieties differ markedly in their susceptibility to kernel smudge, and that, in general, durum wheats are more susceptible than are hard red spring wheats. The behaviour of the varieties was quite constant for different stations and years. The results in Tables 1 and 2 indicate that, in the development of seed discolorations in wheat, the variety of wheat involved is a factor of considerable importance.

To obtain more information concerning the relative susceptibility to kernel smudge of durum and hard red spring wheats, an examination was made of the car lot inspection records of the Western Grain Inspection Division, Department of Trade and Commerce, Winnipeg, Manitoba, for the crop years 1939–42, inclusive. The data obtained (Table 3) showed that in each of the 4 years 1939 to 1942, a higher percentage of the cars of durum wheat grown in Western Canada and inspected at Winnipeg contained kernel smudge than did those of hard red spring wheat. In 1940 and 1941 the losses from this disease in durum wheat, owing to the lowering of the commercial grade, reached appreciable proportions, particularly in Manitoba.

TABLE 3.—PREVALENCE OF KERNEL SMUDGE IN CAR LOTS OF DURUM AND HARD RED SPRING WHEAT PRODUCED IN WESTERN CANADA AND INSPECTED AT WINNIPEG IN 1939, 1940, 1941, AND 1942

Crop	Class of wheat	Number of cars inspected[1]	Percentage of cars with kernel smudge
		No.	%
1939	Durum Hard Red Spring	3,631 103,250	0.3 0.0
1940	Durum Hard Red Spring	447 24,498	14.0 3.8
1941	Durum Hard Red Spring	202 15,397	5.0 1.4
1942	Durum Hard Red Spring	934 15,644	2.7 0.1

[1] Cars inspected by Western Grain Inspection Division, Department of Trade and Commerce, Winnipeg, Man., from August 1 to October 31.

Since 1935 there has been, in respect to the varieties and the extent to which they are grown, a remarkable change in the wheat crop of Western Canada. In 1935, for instance, the acreage occupied by durum wheat in Manitoba was 39% of the total wheat acreage; whereas in 1942, it was only 5%. Furthermore, certain rust susceptible varieties of hard red spring wheat, such as Marquis and Reward, have virtually disappeared from Manitoba and southern and east central Saskatchewan. As a matter of fact, the introduction of rust resistant varieties has made such rapid progress in these areas that in 1941 and 1942, four varieties, Thatcher, Apex, Renown and Regent, occupied more than 90% of the wheat acreage in Manitoba and approximately 80% in Saskatchewan (9). In view of

this condition, information concerning the relative susceptibility to kernel smudge of the varieties of spring wheat now commonly-grown in Western Canada is of particular interest.

Data on the reactions to kernel smudge of 6 standard spring wheat varieties, including the stem rust resistant varieties, Thatcher, Apex, Renown, and Regent, were obtained in the 8 years 1935–42. These varieties were grown each year in co-operative tests conducted by the Subcommittee on Plant Breeding[4] at from 5 to 6 stations in Manitoba, from 3 to 7 in Saskatchewan, and from 3 to 6 in Alberta. A summary of the kernel smudge data is given in Table 4.

TABLE 4.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF CERTAIN STANDARD VARIETIES OF HARD RED SPRING WHEAT GROWN AT SEVERAL STATIONS IN WESTERN CANADA IN THE 8 YEARS 1935–42

Variety[1]	1935 (13)[2]	1936 (11)	1937 (12)	1938 (14)	1939 (17)	1940 (17)	1941 (15)	1942 (14)	Average (1935–42)
	%	%	%	%	%	%	%	%	%
Apex	4.8	0.4	8.2	4.0	1.8	3.5	7.2	2.6	4.1
Thatcher	2.4	0.2	5.1	2.3	0.5	2.1	3.0	1.2	2.1
Marquis	2.4	0.0	1.9	1.2	0.1	1.3	1.5	1.1	1.2
Renown	2.0	0.1	1.9	2.1	0.1	0.5	0.4	1.2	1.0
Regent	2.0	0.1	1.9	1.7	0.0	0.2	0.5	1.1	0.8
Garnet	0.0	0.0	0.0	Tr.	0.0	0.0	Tr.	0.1	Tr.
Average	2.3	0.1	3.2	1.9	0.4	1.3	2.1	1.2	—

Tr. = Trace of kernel smudge (less than 0.1%).
[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Number of stations in Western Canada at which the varieties were grown.

Table 4 gives the average annual kernel smudge percentages for all stations at which the varieties were grown. These data show that, each year from 1935 to 1942, Apex was more susceptible to kernel smudge than was any of the other varieties tested. Garnet, an early maturing variety, was the most resistant. Of the stem rust resistant varieties tested, Renown and Regent were consistently more resistant than were Apex and Thatcher. Although the varietal reactions to this disease were quite constant at the different stations and for the 8 years, the resistant variety Garnet, and the susceptible variety Apex, showed less tendency to vary between stations or between years than did the moderately susceptible or moderately resistant varieties.

A special variability study of susceptibility to kernel smudge was made in 1942 with 4 pure lines from reciprocal crosses between Thatcher and Regent. These were grown, along with certain standard varieties at 5 stations in each of the Prairie Provinces. Grain samples of each line and variety, obtained from each of the 15 stations, were examined for the presence of discoloured kernels. The results of this study are summarized in Table 5.

[4] Associate Committee on Field Crop Diseases (Western Section), National Research Council and Dominion Department of Agriculture, Canada.

TABLE 5.—MEAN PERCENTAGE OF KERNEL SMUDGE IN THE THRESHED GRAIN SAMPLES OF CERTAIN STANDARD VARIETIES AND PURE LINES FROM CROSSES BETWEEN THATCHER AND REGENT, GROWN AT 5 STATIONS IN EACH OF THE PROVINCES, MANITOBA, SASKATCHEWAN, AND ALBERTA, IN 1942

Variety or line[1]	R.L. No.[2]	Manitoba	Saskat-chewan	Alberta	Average (15 stations)
		%	%	%	%
Thatcher × Regent	2012	14.3	6.5	5.5	8.8
Regent × Thatcher	2038	5.7	2.8	2.4	3.6
Apex	1342	4.3	1.4	1.1	2.3
Thatcher × Regent	2027	3.6	1.0	0.8	1.8
Regent	975.6	2.7	0.8	0.6	1.4
Thatcher × Regent	2041	2.8	0.5	0.5	1.3
Thatcher	1945	1.6	0.4	0.5	0.8
Garnet	15	0.0	0.0	0.3	0.1
Average	—	4.4	1.7	1.5	—

[1] Varieties arranged according to the percentage of kernels affected by kernel smudge.
[2] Rust Laboratory Number, Cereal Division, Dominion Rust Research Laboratory, Winnipeg, Man.

The data in Table 5 show that pure lines from crosses between Thatcher and Regent differed appreciably in their reactions to kernel smudge. Of those tested, R.L. 2012 was highly susceptible to the disease, whereas R.L. 2041 showed considerable resistance to it. Data for individual stations showed that significant differences existed between the different standard varieties and lines in their reaction to kernel smudge, and that the comparative varietal differences were quite constant at the 15 widely separated stations.

In 1942, a severe epidemic of leaf rust (*Puccinia graminis* Erikss.) occurred in Western Canada. In consequence, the incidence of kernel smudge was lower in the leaf rust susceptible variety Thatcher than in Regent, a variety possessing considerable resistance to leaf rust. As the results in Table 5 show, in 1942, the incidence of kernel smudge was considerably higher in Manitoba than in Saskatchewan and Alberta.

RELATIVE SUSCEPTIBILITY OF WHEAT TO KERNEL INFECTION BY SMUDGE-PRODUCING FUNGI

With the object of determining the presence and prevalence of smudge-producing fungi in the kernels, a large number of farm samples of Apex, Thatcher, Renown, and Regent seed from the 1938, 1939, 1940, 1941, and 1942 crops in Manitoba were examined for kernel smudge and subjected to a plate test. The percentage of kernel smudge in each sample was determined by an examination of three 100-kernel lots selected at random from each seed sample. To determine the internal fungous flora of the seed, 100 surface sterilized kernels of each sample were plated out on potato dextrose agar in Petri dishes. The plating methods used in other cereal seed studies were employed (7). The results of the plate tests and kernel smudge determinations are summarized in Table 6.

TABLE 6.—MEAN PERCENTAGE OF KERNELS INFECTED WITH *Alternaria* SPP., *Helminthosporium sativum*, AND OTHER FUNGI, AND EXHIBITING KERNEL SMUDGE, IN GRAIN SAMPLES OF APEX, THATCHER, RENOWN, AND REGENT WHEAT PRODUCED IN MANITOBA IN THE 5 YEARS 1938–42

Year and variety	Number of samples tested[1]	Mean percentage of kernels infected with:				Mean percentage of kernels smudged
		Alternaria spp.	*Helminthosporium sativum*	Other fungi[2]	Fungus-free seeds	
	No.	%	%	%	%	%
1938						
Thatcher	44	80.3	4.3	1.4	15.2	6.7
Renown	23	76.2	3.6	2.9	18.5	2.2
1939						
Apex	4	66.5	1.8	8.3	25.0	1.6
Thatcher	123	62.5	2.8	3.8	31.9	1.2
Renown	104	52.6	1.7	6.1	40.1	0.2
Regent	21	48.5	2.2	6.9	44.2	0.2
1940						
Apex	5	76.4	3.6	4.6	19.2	7.3
Thatcher	189	76.1	3.1	2.7	19.8	5.7
Renown	132	70.1	2.9	6.1	24.8	1.1
Regent	55	59.8	2.7	6.9	35.1	1.0
1941						
Apex	4	79.0	6.2	4.0	14.2	4.9
Thatcher	223	79.8	6.9	4.3	13.7	3.5
Renown	88	74.5	5.1	6.3	17.4	2.5
Regent	64	65.7	5.6	6.8	24.5	2.4
1942						
Thatcher	53	79.0	5.4	3.4	13.9	0.7
Renown	27	77.8	4.4	4.4	15.9	1.3
Regent	41	77.4	4.1	3.7	16.0	2.4

[1] One hundred seeds of each sample were surface sterilized and cultured on potato dextrose agar in Petri dishes.
[2] Chiefly fungi belonging to the genera *Nigrospora*, *Fusarium*, *Curvularia*, *Hormodendrum*, *Epicoccum*, *Septoria*, *Macrosporium*, and *Penicillium*.

The plate test results in Table 6 show that there were marked differences between varieties in their susceptibility to internal seed infection by species of *Alternaria* and *Helminthosporium sativum*, the fungi commonly associated with kernel smudge. Annually, from 1939 to 1942, the kernels of Apex and Thatcher were somewhat more severely infected with these fungi than were the kernels of Renown and Regent. In all years, more fungus-free kernels were found in Regent than in Renown, and considerably more than in Thatcher. On the other hand, a visual examination of the grain samples for discoloured kernels showed that Apex and Thatcher wheat seed produced in Manitoba in 1939, 1940, and 1941 contained more kernel smudge than did Renown and Regent. The results in Table 9 substantiate those presented in Table 4 and indicate that Apex and Thatcher are more susceptible to this disease than are Renown and Regent.

In 1942, owing to the occurrence of a severe leaf rust epidemic in Manitoba, the incidence of kernel smudge was lower in Thatcher and Renown than in Regent. From the literature on the subject, it appears that severe attacks of leaf rust (*Puccinia triticina* Erikss.) result in an appreciable reduction in kernel size (8, 10), and that discolorations typical of kernel smudge are less likely to be found in small shrunken kernels than in large, plump ones (7). Goulden (4), studying the relation between the amount of kernel smudge in a wheat variety and its susceptibility to stem rust (*Puccinia graminis Tritici* Erikss. and Henn.), found that the percentage of kernel smudge in the crop was significantly, but negatively, correlated with degree of infection by stem rust.

DISCUSSION

The results of the present investigation show that varieties of spring wheat differ appreciably in their reaction to kernel smudge, and that varieties and selections of wheat with considerable resistance to the disease are available. Thus, even if it is impossible to obtain varieties that possess complete resistance, it should be practicable to breed wheats that have a high degree of resistance to kernel smudge. Undoubtedly, the growing of resistant varieties is the most practical method of controlling this disease of wheat, barley and rye.

During the 5 years 1938–42, a total of 1200 samples of wheat seed obtained from different districts in Manitoba were examined for kernel smudge and for the presence of fungi in the seed. These studies showed that only a small proportion of the kernels infected with species of *Alternaria* and *Helminthosporium sativum* exhibited discolorations typical of kernel smudge. Thus, it would seem that, although favourable conditions for infection of wheat kernels occur in Manitoba, the environmental conditions that prevail in that province subsequent to infection are usually not favourable for the development of kernel smudge.

In the period under review, field observations have shown that, if the climatic conditions are congenial to the rapid ripening and harvesting of a wheat crop, the incidence of kernel smudge is low; but, if warm, humid weather, with heavy dews, occurs during the later stages of plant growth, the incidence is high. These observations confirm the work of Machacek and Greaney (7) who consider that, in addition to abundance of airborne inoculum and stage of host maturity, the occurrence of favourable climatic conditions, particularly during the later stages of plant growth, is one of the main factors responsible for the severity of kernel smudge in wheat. The results of the present investigation indicate that an important factor affecting the prevalence of this disease in Western Canada is the variety of wheat grown.

SUMMARY

A number of wheat varieties were tested for their susceptibility to kernel smudge caused by species of *Alternaria* and *Helminthosporium sativum* at several stations in Western Canada from 1935 to 1942. In general, varieties of *Triticum durum* were considerably more susceptible to kernel smudge than were those of *T. vulgare*. The commonly grown varieties of

hard red spring wheat tested ranked in order of susceptibility to kernel smudge as follows: Apex, Thatcher, Marquis, Renown, Regent, and Garnet. Garnet, an early maturing variety, was highly resistant to the disease. Of the stem rust resistant varieties tested, Apex and Thatcher proved to be more susceptible than Renown and Regent.

The results of extensive plating tests with a large number of Manitoba samples of Apex, Thatcher, Renown, and Regent seed of the 1939, 1940, 1941, and 1942 crops, showed that the varieties Apex and Thatcher were slightly more susceptible to internal seed infection by *Alternaria* spp. and *H. sativum* than were Renown and Regent. In all years, the percentage of kernels infected internally with these fungi was appreciably higher than the percentage of kernels exhibiting typical external symptoms of smudge. However, it was found that, in years when leaf rust was not a complicating factor, the degree of internal kernel infection was always positively associated with the incidence of kernel smudge in the threshed grain.

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DETERMINATION OF FLESHING CHARACTERISTICS IN MARKET POULTRY[1]

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Attractive appearance unquestionably contributes to the sales appeal of dressed poultry carcasses. Grading regulations therefore endeavour to visualize the disposition of fleshing and the degree of fatness and finish which shall be characteristic of each grade as well as the elimination of blemishes such as tears, pin feathers, crooked keels and breast blisters. While the quantitative recognition of defects does not offer any serious obstacles, the opposite is the case with fleshing and fatness. In commercial grading practice the latter qualities are frankly admitted to be evaluated by subjective impressions. Since these are affected by idiosyncrasies peculiar to the individual grader and by variations in judgment with time and antecedent experience, doubt is raised about their usefulness as adequate tools for estimation of the characters involved. In this connection fleshing is of the greater importance as it is the expression of a genetic factor reacting to given environments at all ages throughout life. Fatness on the other hand is mainly dependent on the biological response of the organism to feeding practice. The aim of the breeder therefore is, in the first place, to learn how to measure muscular development and its attractive disposition on the skeleton of the living bird, and thereafter to find whether statistically significant familial segregation occurs which will render progeny testing for this character feasible.

In an endeavour to show the influence of sires on fleshing and conformation characteristics in their sons Maw and Maw (17) presented X-ray photographs of the progeny of three males. While this pictorial material still left determination of fleshing type to individual observation some concrete data were presented at this time. It was found that the three sires used in this study significantly influenced length of back, keel and shank in their progeny, but had little or no effect on body weight as well as breadth and depth of body. Maw and Maw (18) also found that increase in body length and depth as well as length of leg was inversely correlated to percentage of edible meat, while length of keel and circumference of tibia were positively associated with percentage edible portion. However, none of their correlations seem high enough to have any practical importance. Substantial progress was made when Jaap (7, 8, 9, 10) and Jaap and Penquite (11) devised their method for measuring fleshing by dividing shank length by the cube root of body weight. Jaap found that roundness of breast has greater influence on the monetary value of a bird than any other characteristic. However, he discards determination of breast contour owing to the large experimental error involved in securing

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these measurements on the live birds and states that the relationship of shank length to cube root of body weight proved much superior for use in breeding studies. He acknowledges the poor agreement between results obtained by his fleshing index and by commercial grading. Scott (20) emphasized the disagreement obtained by visual grading and by Jaap's index. Lerner (12, 13) maintained that Jaap's formula is inadequate in that it assumes constancy of the α power in Huxley's (5, 6) relative growth equation and thus throws all the weight of differentiation on the b value. In effect this amounts to the arbitrary selection of a constant slope for all regression curves, and Lumar *et al.* (16) recently mentioned that in biological series such as these the α and b values generally bear an inverse relationship to one another with the result that all the regression curves have a tendency to cross over inside an approximately common area. Dolecek *et al.* (1) devised a technique for grading dressed roasters using several physical measurements for determination of fatness and outward form. Their final score obtained on dressed carcasses is doubtless more nearly correct than routine market grading based on personal intuition can hope to be. However, determination of body shape on living specimens, where softness of tissues and respiratory movement make end points uncertain, will argue against adoption of Dolecek's technique for breeding purposes. It was in fact this uncertainty which led both Jaap and this author to discard such measurements as unreliable criteria for the shape of living birds.

These problems have been studied in this laboratory for several years and since some measure of finality has been arrived at it seems appropriate to summarize results at this time.

EXPERIMENTAL

Results of Initial Tests

It seemed reasonable to assume that some quantitative measure of fleshing would be correlated to grade. The dressed weights of 175 birds of various breeds and sexes were therefore correlated to numerical values assigned to their market grades. The net coefficient of correlation was found to be $+0.348$.

Next, the percentage edible portion from these carcasses as transformed to degrees of an angle by Fisher's (2) formula was analysed by variance. When degrees of freedom and sums of squares were pooled for the various classes the F value exceeded the 0.01 point, but even so no significant difference was found between the numerically most important A and B grades.

When grade values were correlated to the absolute weight of edible portion the net correlation was $+\ 0.503$. The regression was 215 gm. between succeeding grades, hence the average difference of edible portion between carcasses of the highest and lowest of the four grades would be 645 gm. However, in view of the relative uncertainty of determination implied by a moderate correlation commercial grading could not be accepted as a reliable measure of the quantity of meat on a carcass. Furthermore when the main object is to evaluate market qualifications from quantitative estimates of fleshing in the living bird the problem becomes somewhat more involved.

Subsequent Experiments

During earlier work it had been found that roughly from 60 to 80% of the dressed carcass weight constituted the edible portion. It was therefore argued that if two birds were of identical skeletal size the heavier one of the two would probably be possessed of the largest muscular mass and so, it was reasoned at the time, be the plumper one of the two. The immediate object would therefore seem to be a determinaion of the deviations of observed from expected body weight relative to skeletal size, the magnitudes of these deviations to decide the relative merits of the individual birds. The allometric law $x = by^{\alpha}$ would serve this purpose when weight was treated as the dependent and skeletal size as the independent variable.

For the purpose of testing this hypothesis 50 Barred Rock and 66 White Leghorn cockerels were killed at 29 weeks of age. For both breeds these birds constituted all surviving male progeny from 11 matings to 5 sires with at least 2 matings to each sire. All birds were weighed after being starved overnight and various skeletal measurements secured. They were then killed, dressed, graded and stored at 10° F. below zero. On removal from storage a transverse section about 5 to 8 mm. thick was sawed out of the frozen carcass immediately forward of the anterior point of the keel and a careful tracing made of the posterior face of this section. The pectoralis major, secundus and tertius were then freed at their insertions on the humerus and dissected out and weighed. The muscles of the posterior extremities from the sartorius to the semitendinosus were likewise freed at their origin on the ilium, sacrum and ischium, dissected out and weighed to the nearest 0.1 of a gram. These muscles represent all of the edible portion except the skin and muscles on neck and wings. Total edible portion was determined by difference between the weight of the dressed carcass and the combined weights of head, feet, offal and bones.

Indices of Relative Roundness of Breast Muscular Weight and Skeletal Size

The chosen transverse section through the birds presents the maximum width and roundness of the breast at the point where the full depth of the sternum is likewise manifest. The relative roundness of these seations was repeatedly found to coincide almost perfectly with the rank numbers of carcasses that had been aligned according to attractiveness of fleshing. Throughout this work such sections have therefore been used as the most critical record obtainable of attractive conformation.

In order to justify body weight as an index of muscular development the former was correlated to edible portion from all 116 birds. The net coefficient of correlation within breeds was +0.942 and starved live weight was therefore accepted as an index to weight of musculature.

On correlating the various skeletal measurements it was found that the length of all long bones bears a close relationship one to the other, their coefficients of correlation being of the order of +0.8. All other bones were found to be poorly correlated, and length of the long bones therefore determines body size more consistently than any other skeletal measurement. Moreover the length of one long bone will be a fair index of general size. The lengths of tibia and metatarsus are of all long bones the most easily secured in live specimens. On correlating the length of each bone

as measured on the live birds with its length when clean and air-dried the coefficients were found to be for tibiae +0.944 and for metatarsae +0.838. The mean error between expected and observed live measurements were for tibiae 0.93% and for metatarsae 1.51%. In our hands therefore, tibiae were measured slightly more accurately than metatarsae and hence were adopted as indices of skeletal size.

Determination of Relative Fleshing

Having justified the indices for muscular weight and skeletal size the regression of log body weight (x) on log tibia length (y) were secured for the two breeds as shown in Table 1.

TABLE 1.—MEAN INDICES, LOG CORRELATIONS AND LOG REGRESSIONS

	Mean body wt.	Mean tibia	Log r	Log regression equation
	gm.	mm.		
Barred Rock	3124.5	180.3	+0.340	$x = 1.06055 + 1.07904\, y$
White Leghorn	2126.2	157.3	+0.726	$x = -0.71778 + 1.84162\, y$

From the log regression equations, the expected body weight in actual numbers relative to the observed tibia length was calculated for each individual bird. The deviations between these and observed body weights which hereafter are referred to as "Fleshing Index" were secured and correlated to the combined actual weights of pectoral and leg muscles. The net correlation coefficient within tibia length classes of 2 mm. for Leghorns and 4 mm. for Rocks were +0.912 and +0.938 respectively. It is apparent that deviations of expected from observed body weights as secured from the size weight regression estimate relative fleshing with precision.

Relationship of Relative Fleshing to Plumpness

The tracings of frozen sections were ranged in descending order according to the value of their fleshing indices. This array revealed that relative fleshing is not necessarily a good criterion of plumpness. Thus a very well fleshed carcass might often be of quite poor appearance on account of excessive depth of carcass. On the other hand mediocre relative fleshing might be coupled with plump appearance provided the carcass was sufficiently shallow. The two birds, sections of which are shown in Figure 1, had approximately the same body weights and tibia lengths and consequently very nearly identical fleshing indices. In spite of this the two carcasses differed radically in plumpness and grading appeal.

This was accounted for by the difference in dorso-ventral depth which was 126 mm. in one and 144 mm. in the other. This difference in anatomical conformation of the thoracic skeleton necessitated that almost identical volumes of pectoral muscle in one bird be laid down in thin, broad bundles giving it a slabsided appearance, and in the other deposited in thick rounded muscles giving it a plump appearance.

Since there is small virtue in segregating large fleshing volume if its attractive distribution is neglected, it therefore becomes necessary to take account of depth of body as well as of fleshing index. This may be accomplished by obtaining the deviations of observed from expected fleshing indices relative to body depth or by securing the deviation of observed from expected body weight relative to the geometric mean of tibia length and body depth. These values, which have been termed "Grading Indices" placed the sections of the birds in their proper order of merit as regards smooth roundness of contour with very few errors. The grading index thus is a numerical expression of attractive appearance and is arrived at by referring body weight to two important indices of body

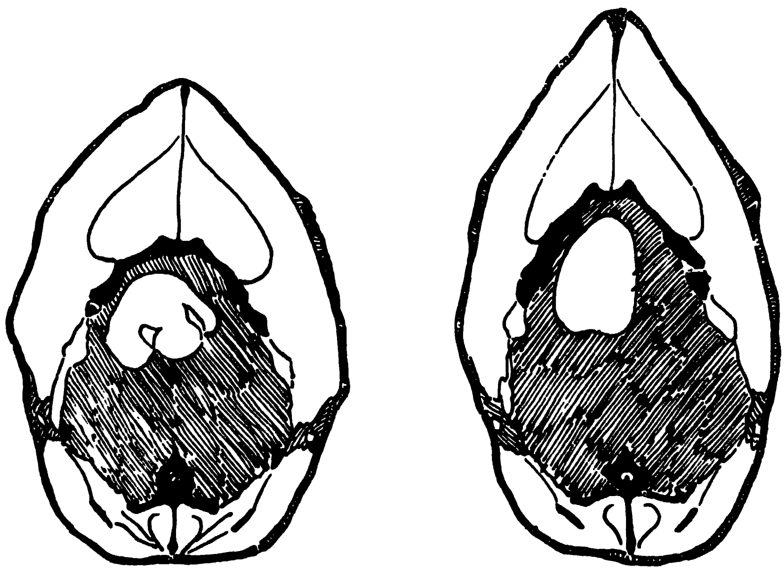

FIGURE 1. Transverse sections immediately forward of anterior point of keel. *Left*—Barred Plymouth Rock cockerel No. 592. Starved live body weight 3418 gm., length of tibia 183 mm., fleshing index 242 gm. body depth 126 mm. *Right*—Barred Plymouth Rock cockerel No. 306. Starved live body weight 3468 gm., length of tibia 185 mm., fleshing index 255 gm., body depth 144 mm. Reduced ½ diameter of natural size.

size namely, length of tibia and depth of thoracic skeleton. However, the errors that do occur in determination of body snape by the grading index, although few may be quite pronounced. These errors are due mainly to excessive individual deviations from mean keel length. An extraordinarily long keel may detract from the round appearance of a breast whereas a very short keel may enhance it. Since the few radical departures from the relatively normal keel lengths which are capable of introducing these disturbances are entirely unpredictable it will be found advisable in breeding operations to consider superior fleshing index and moderate to small body depth separately. Desirable families will then be those that excel in both characters.

Breeding for Improved Market Type

The two samples of 50 Rocks and 66 Leghorns served to test the usefulness of this scheme. The records of each breed were separated in their 11 full brother groups and the relationship between fleshing indices and

total weight of pectoral and leg muscles analysed by covariance. The net correlation coefficients within brother groups of Rocks and Leghorns respectively were +0.825 and +0.801 even when all sizes of brothers were pooled. However, the variance analysis of fleshing indices yielded the valuable information that whereas the Rocks showed highly significant difference between full brother groups this was far from being the case for the Leghorns. Furthermore, similar analyses of body depth showed highly significant differences between the full brother groups of Rocks and none for the Leghorns. In these two samples, segregation of superior market type would therefore have been very promising in the Rocks and quite purposeless in the Leghorns.

Commercial Grading in the Light of Concrete Determinations of Fleshing and Fat

The success or failure of any effort directed towards the breeding of improved market type must ultimately be judged by its impact on commercial grading results. It therefore becomes important to analyse the reliability of routine commercial grading.

Canadian grading standards specify separately the disposition of flesh and fat for each grade and grading practice endeavours to assay these factors independently. The official Canadian "Regulations Respecting the Grading and Marketing of Dressed Poultry" (19) which were applied in these tests by officials of the Dominion Marketing Service contain specifications for fleshing and fatness as set forth in Table 2.

TABLE 2.—OFFICIAL GRADING REQUIREMENTS

Grade	Fleshing in relation to length and depth of body	Fat over breast back hips and pin bones
"Special"	Well fleshed, breast full	Well covered
"A"	Relatively well fleshed slightly prominent keel will not disqualify	Well covered
"B"	Reasonably well fleshed insufficient to meet grade A requirements	Sufficient to prevent a dark red appearance
"C"	Fairly well fleshed	

Although fat is not important in a breeding scheme its value as a preventive against dehydration during storage and cooking, as a generally accepted aid to finish and bloom, and as a producer of flavour in roasting secures for it important consideration in market grading. Gutteridge (3, 4) has shown that fat is laid down in the various depots in an orderly manner and approximately gram for gram subcutaneously and abdominally. Also that samples of the pectoral feathertracts yield practically perfect indices to the general fatness of carcasses.

For the purpose of determining the relative accuracy of market grading a small sample of 23 Barred Rocks was secured. The dressing and sampling procedure as outlined above was applied with the addition that a transverse section of the pectoral feather tract was taken for fat determination. In Table 3 is presented the manner in which commercial grading segregated the actual percentages of fat, as expressed in degrees of an angle.

TABLE 3.—DISTRIBUTION OF FATNESS BY VISUAL GRADING

Grades	Fat Determinations										
Special and A	50.0	48.8	48.4	46.2	45.0	44.5	42.9	39.8	38.1		
B	44.5	44.4	41.9	41.8	41.4	39.1	38.2	36.7	36.6	30.0	29.6

3 Samples lost.

The mean for the whole distribution is 41.39 ± 5.56 and although the statistical difference between the two grades therefore is of unquestionable significance, considerable overlapping does occur. Let it be assumed that the mean value had acted as the point of segregation for the fatness characteristic of the higher grade from that of the lower one. It will then be seen that the smallest value which commercial grading deemed worthy of the superior grading was not quite one standard error lower than the mean, and the highest value referred to the inferior grade was higher than the mean by the same amount. It may therefore be estimated that approximately the 50% of all determinations which are grouped closest to the boundary between the grades are liable to misplacement by routine grading. Consequently, it is only pronounced fatness or leanness respectively which visual observation is able to appreciate with certainty.

When grading practice attempts to estimate fleshing separately the breast is considered exclusively. Moreover, it is the attractive appearance of the breast and not its quantitative fleshing which is being estimated. The latter has only importance as the raw material from which roundness of breast may be formed.

At the time when the carcasses were commercially graded the operator also placed them in alignment from the most attractive to the poorest in order of merit.

In Table 4 is presented the manner in which commercial grading distributed the alignment numbers to the various grades. Below these numbers are shown the calculated grading indices for each carcass. Index values which did not truly represent the appearance of the birds as judged by the cross-sections are marked by an asterisk.

TABLE 4.—DISTRIBUTION OF ALIGNMENT NUMBERS AND INDEX VALUES TO COMMERCIAL GRADES

Grade	Alignment numbers and indices									
Special	1 93*	2 490	3 376	5 253	8 174	9 93*	11 151	17 210*		
A	4 300′	6 288	7 177	10 124	12 70	13 16	14 62	15 16 134* −76	18 11	19 −132	20 1*
B	21 −173		Grade C			22 −568		No grade		23 −925	

It is apparent that commercial grading was as unreliable in estimation of attractive appearance of fleshing as it had been in evaluating fatness since considerable overlapping occurred between the grades.

Commercial grading can therefore only be accepted with the reservation that all its decisions regarding borderline cases between grades, whether for fatness or for fleshing, are subject to error.

DISCUSSION

In the light of a great volume of published data to that effect, it is probably by now agreed that total body weight may be regarded as relatively unimportant to egg production. The most pertinent consideration of body weight is consequently its market value and its segregation into types may therefore proceed without complicating consideration of other factors.

At the present time practically all poultry flocks exhibit a wide variety of sizes and shapes and are accordingly degraded when brought to market. Breeding for improved market type therefore resolves itself into efforts towards elimination of the prevailing variation by segregating and standardizing families of uniformly good type within those breeds in which the precise fleshing index as well as thoracic depth show significant familial segregation.

Routine grading serves as an estimate of market value and will continue to be indispensable to commercial practice for reasons of speed and convenience in spite of the lack of precision inherent in this method. The native inexactitude is fundamental because such grading involved that each carcass must be evaluated separately without any but a mentally recorded standard, and the errors to which this led was shown by the discrepancies between commercial and alignment grading. In the latter method each specimen is compared to others and the order of merit thus arrived at agreed almost perfectly with a similar arrangement of the frozen cross sections. In fact, alignment grading is probably the nearest possible approach to faultless grading. However, alignment grading is for obvious reasons impracticable for commercial grading as well as for breeding purposes. Nevertheless the superior nature of alignment grading suggests that commercial grading might benefit by ready reference to pictorial borderline standards. At present the best that can be said for commercial grading is that about half of the birds which rightly belong in any one grade will be correctly graded while the others have an equal chance of being placed in one of the adjoining grades. In other words there is a strong tendency for good birds to get a high grading and for poor ones to be graded low, without the individual grades possessing the character of definite quality designations. Commercial grading can therefore not be accepted as a tool for segregating superior market type but it will over a period of time act as a sieve which will determine, albeit rather coarsely, whether the average quality of all meat stock improves or remain static.

Lloyd and Clandinen (15) and Lloyd (14) reported improvement in market conformation of two breeds obtained by the method of grading breeding birds for U, V, and I shape of the breast. When progress can be attained by such a relatively inexact technique it is safe to assume that breast shape is dependent on quite few genes for its expression. These authors rightly state that deep bodied birds are of low grade but incorrectly assume that slabsided birds carry little meat on the breast. The method which has been evolved and herein presented is capable of supplying precise quantitative determinations of relative volume of fleshing and thus giving numerically expressed measures of the material whereof roundness of breast may be created. When at the same time selection is practised for shallowness of torso attractive appearance cannot fail to be secured within a relatively short span of time since both characters show familial segregation.

SUMMARY

A technique has been evolved for accurate determination of relative fleshing from exact measurements on living birds.

This measure of fleshing, which has been termed Fleshing Index, is the deviation of actually observed from expected body weight relative to skeletal size as indicated by the length of tibia. It is obtained through the logarithmic regression of body weight on tibia length. That this index is an accurate measure of fleshing is shown by the fact that the calculated deviations are almost perfectly correlated to the actual weight of combined breast and leg muscles which were dissected off the carcasses.

However, a large volume of flesh which happens to be deposited on a carcass of excessive dorso-ventral depth through the thoracic region will produce a poor type. Inversely a good type may be the product of a moderate volume of flesh and a relative shallow body. Hence consideration of depth of torso must proceed simultaneously with determination of fleshing index when market type is considered.

Commercial grading has a pronounced tendency to award superior grading to high quality carcasses and inferior grade to poor ones. However, considerable overlapping occurs among specimens that approach the boundaries between grades. This is equally true for fleshing type and for fatness. Individual grades therefore lack the character of definite quality designations. Hence, routine market grading is unreliable as a basis for selection of breeding worth. Since fleshing indices and thoracic depth alike showed familial segregation in the Barred Rock breed these precise criteria of fleshing type may be used advantageously as progeny testing tools for market type in this breed.

ACKNOWLEDGMENTS

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STUDIES RELATING TO FERTILITY IN ALFALFA (*MEDICAGO SATIVA* L.)

II. TEMPERATURE EFFECT ON POLLEN TUBE GROWTH[1]

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It has long been realized that temperature has a profound effect on certain biological processes. The relationship of temperature to pollen tube growth has been studied for several plant species, but as far as is known, there is no published report of studies made on alfalfa. Therefore, during the summer of 1939, some tests were conducted to ascertain the responses of pollen tube growth to different temperatures.

LITERATURE REVIEW

Sandsten (6), using the pollen of apples and plums germinating on a cane sugar solution, obtained an increase in growth rate of the pollen tubes with an increase in temperature (86° to 93.2° F.).

Working with *Datura*, Buchholz and Blakeslee (4) found that within limits, the growth rate of pollen tubes increased as the temperature increased. They tested the tube growth in pistils, using a temperature range of 52° to 98.5° F. The growth rate increased steadily from 52° to 92° F., with a slight decline at 98.5° F.

Smith and Cochran (7) concluded that a temperature between 70° and 85° F. was optimum for pollen germination and tube growth in the tomato. Germination was poor at both 50° and 100° F.; and tube growth, while slow at both temperatures, was more limited and irregular at 100° F.

Cummings *et al.* (5) found that on 4/10N sucrose- and glucose-agar media, the tubes of pear pollen grew more rapidly at 80° than at 58° F. They also found that in the pistils, the growth rate of the tubes was less at 58° than at 80° F.

MATERIALS AND METHODS

Table 1 lists descriptive information for the 3 alfalfa plants used for this study. These 3 plants were among the ones collected and classified by Bolton (2), and were grown in an isolation screenhouse. All were classed as fertile and had an erect growth habit.

TABLE 1.—LIST OF PLANT MATERIAL

Plant designation	Strain and plant number	Varietal origin	Flower colour
4	I.31.9 (21–23)	Grimm	Light purple
5	S[1].32.32 (47–5)	Cossack	Bluish
6	I.28.18 (14–38)*	Grimm, Disco	Medium purple

* This plant is the same as I.28.18 (8-28), and designated as 8-28f by Bolton and Fryer (3).

[1] A portion of a thesis presented to the Committee on Graduate Studies, University of Alberta, in partial fulfilment of the requirements for the degree of Master of Science.
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Because of the difficulty of detecting the stained pollen tubes in the styles, all samples were collected one-half hour after the flowers were tripped so that the tubes could be readily stained and measured while still in the stigma.

The temperatures used for this experiment were obtained in various places, and these will be referred to as "stations" in the text.

A temperature of 50° F. was obtained in a large cooling chamber equipped with a refrigeration unit. Another "station" was established in the anteroom of the above mentioned cooling chamber and was held at a temperature of 70° F. A series of three temperature cabinets in the greenhouse was maintained at 70°, 80° and 90° F. For the temperature of 100° F., an incubation oven in the laboratory was employed.

The temperatures at these "stations" fluctuated somewhat, but during the half-hour periods when the tests were made, the temperature changes were very small. Temperatures recorded for the different "stations" were those registered at the time the tests were carried out.

Stem cuttings of the alfalfa plants in bottles of tap water were placed in the various "stations" at least 12 hours prior to the test period. Ten to 12 flowers were tripped on each cutting, and after one-half hour were removed from the temperature "stations" and treated in the following manner.

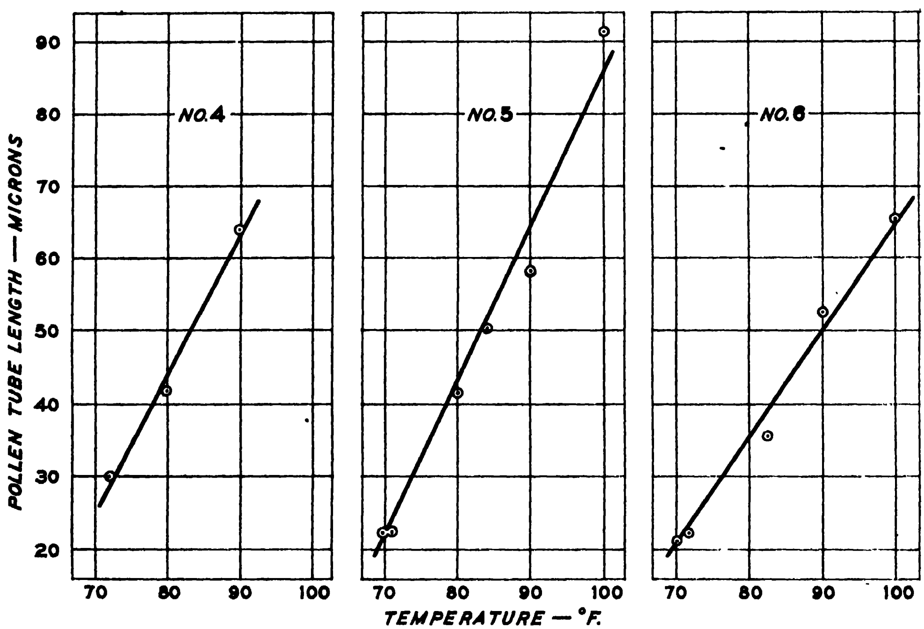

FIGURE 1. Temperature effect on pollen-tube growth during half-hour periods.

The pistil was dissected out from the surrounding floral parts, and the stigma and style removed in one piece by clipping with a pair of scissors. This portion was then placed on a microscope slide in a killing and staining solution, a cover-glass applied, and by pressure applied to the cover-glass the stigma was slightly crushed and spread.

The killing and staining solution was suggested by Armstrong and White (1). It consisted of lacto-phenol, to which was added a small amount of an acid fuchsin—light green stain. The stain was made up of 8 parts of 1% aqueous acid fuchsin and 2 parts of 1% light green in 95% alcohol.

Six stigmas were collected at each temperature for a single determination. Measurements of the pollen tubes were made with the aid of an ocular micrometer, at a magnification resulting from the use of a 4 mm. objective in combination with 10× oculars. Measurements were recorded as units of the micrometer scale and later changed to microns.

EXPERIMENTAL RESULTS

The results from the tests are presented in Table 2. These results are summarized in Table 3, and a graphic representation is to be seen in Figure 1.

In no case did the pollen germinate at 50° F. in the allotted half-hour period. A slight bulging at the germ pores was seen in most instances, but no real pollen tubes had been formed. At all other temperatures, germination appeared to be quite normal, though no counts were made.

TABLE 2.—TEMPERATURE EFFECT ON POLLEN TUBE GROWTH DURING HALF-HOUR PERIODS

Plant designation	Date	Temperature degrees F.	"Station"	Number of stigmas	Number of tubes measured	Mean length of tubes
						microns
4	28/7/39	72	Chamber	6	40	31.91 ± 1.283*
		80	Cabinet	6	29	40.46 ± 2.314
		90	Cabinet	5	32	68.11 ± 3.065
	29/7/39	72	Chamber	5	41	28.39 ± 1.182
		80	Cabinet	5	37	43.72 ± 2.335
		90	Cabinet	2	12	53.70 ± 6.166
5	1/8/39	50	Chamber	6	0	No germination
		70.5	Chamber	4	24	22.16 ± 1.122
		70	Cabinet	4	33	23.39 ± 1.501
		80	Cabinet	6	36	41.80 ± 2.321
		90	Cabinet	6	54	58.22 ± 2.653
	3/8/39	50	Chamber	6	0	No germination
		70	Chamber	6	43	20.85 ± 0.706
		70	Cabinet	4	33	22.66 ± 1.241
		84	Cabinet	3	22	50.71 ± 3.071
		90	Cabinet	2	5	58.37 ± 4.650
	4/8/39	100	Oven	5	38	91.84 ± 4.812
	5/8/39	100	Oven	3	22	91.06 ± 6.659
	4/8/39	50	Chamber	5	0	No germination
		71.6	Chamber	5	28	22.15 ± 1.148
		70	Cabinet	4	23	21.81 ± 1.450
		82.4	Cabinet	6	104	35.90 ± 1.305
		90	Cabinet	5	48	52.56 ± 2.873
		100	Oven	4	29	68.87 ± 4.845
	5/8/39	50	Chamber	4	0	No germination
		70	Cabinet	4	31	21.08 ± 0.857
		100	Oven	2	15	58.78 ± 3.710

* Standard Error of the mean.

The results indicate that there is a linear relationship between the length of the pollen tubes and the temperature, this relationship holding for temperatures from 70° to 100° F. for the half-hour period.

TABLE 3.—SUMMARY OF DATA ON TEMPERATURE EFFECT ON POLLEN TUBE GROWTH

Plant designation	Temperature degrees F.	measured Number of tubes	Mean* length of tubes (microns)
4	72	81	30.14
	80	66	42.28
	90	44	64.19
5	70	109	22.17
	70.5	24	22.17
	80	36	41.80
	84	22	50.71
	90	59	58.22
	100	60	91.55
6	70	53	21.80
	71.6	28	22.15
	82.4	104	35.89
	90	48	52.57
	100	44	65.43

* Weighted means derived from data in Table II.

An examination of the standard errors of the mean pollen-tube lengths (Table 2), would lead to one of two inferences. Firstly, that tube length is more variable as the mean length increases; or secondly, that growth rate differential is greater at the higher temperatures than at the lower temperatures. Neither of these inferences can be confirmed by reference to the data given. However, pollen-tube measurements made in another study, to be reported in a later paper, indicate that the variability in pollen-tube length increases with an increase in the mean length.

Microphotographs were made from the prepared material, and these are to be seen in Figures 2 and 3.

DISCUSSION

The results obtained in the aforementioned studies indicate that pollen tubes grow more rapidly as temperature increases. It must be remembered, however, that in the half-hour test period, two distinct processes occurred. These were germination and pollen-tube elongation. As has been shown by other workers for different plant species, the germination rate is affected by temperature, being more rapid at higher temperatures.

It is of interest to note the tube growth at 100° F. (Table 3 Figures 2 and 3), which appeared to be quite normal. At this same temperature Smith and Cochran (7) found the pollen-tube growth of tomato to be very poor; the length, even after 54 hours, not being as great as the length attained in 12 hours at temperatures of 70° and 85° F.

The plants tested in these experiments were classed as fertile, and each set pods quite freely on selfing. The reaction of the pollen tubes of poorer pod-setting plants to temperature is not known. It may be that the tubes of such plants behave in a somewhat different manner, thus accounting, in part, for the poorer pod- and seed-setting.

FIGURE 2. Pollen-tube growth of plant No. 5 during half-hour period. × 65. Grain with tube corresponding to mean length marked by a white cross.

Legend	Temperature	Station
1	50° F.	Chamber
2	70° F.	Chamber
3	70° F.	Cabinet
4	84° F.	Cabinet
5	90° F.	Cabinet
6	100° F.	Oven

FIGURE 3. Pollen-tube growth of plant No. 6 during half-hour period. × 65. Grain with tube corresponding to mean length marked by a white cross.

Legend	Temperature	Station
1	50° F.	Chamber
2	70° F.	Cabinet
3	71.6° F.	Chamber
4	82.4° F.	Cabinet
5	90° F.	Cabinet
6	100° F.	Oven

SUMMARY

A linear relationship was found to exist between pollen-tube growth and temperature, the length increasing as the temperature increased from 70° to 100° F.

At 50° F. no germination occurred in one-half hour although a slight bulging at the germ pores of the pollen grains could be seen.

The pollen tubes formed at 100° F. were normal in appearance with no irregularities such as have been described for the pollen tubes of other plant species growing at this same temperature.

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BOOK REVIEW

THE BATTLE OF THE LAND. By N. Gangulee. Published by Lindsay Drummond, London, Eng. Price 6s.

The author, who was formerly Professor of Agriculture and Rural Economics in the University of Calcutta, India, and now is a Research Scholar at Rothamstead Experimental Station, has made an extensive study of the food production campaign in wartime Britain. Sir E. J. Russell in a foreword states that "As a trained agriculturist, Professor Gangulee is able to appraise at their full value the significance of these varied developments. He has searched the available records, ahd in order to avoid possibilities of error has quoted fully from them. His judgments are kindly, sympathetic and well balanced....".

This is a small book running to 135 pages, but it contains a large amount of information. Part I on the Campaign for Food Production, treats of the extension of arable farming, mechanization, land reclamation, maintenance of fertility, and the contribution of small holdings and allotments to food production. Part II discusses the Land Army and includes material on farm wages and housing. Part III on the Food Front includes statistics and discussions on arable crops, livestock farming, milk and milk products, and the problem of feeding the nation.

Illustrations include six pictorial diagrams, sixteen pages of photographs, and two page-size maps on land classification of England and Wales, and types of farming in England, Scotland and Wales. Appendices include a summary of the Land Fertility Scheme and the Agricultural Goods and Services Scheme, a Cost of Living Index to December, 1942, and an index of Retail Food Prices to December, 1942.

This is a useful publication for any one desiring a general summary of Britain's wartime agricultural production policies and their effect on British agriculture.

H. L. TRUEMAN.

ERRATUM

In the article entitled, "An estimate of loss in Manitoba from common root rot in wheat", by J. E. Machacek, October 1943 issue of *Scientific Agriculture* (Vol. 24, No. 2), on page 76 the last sentence of the Discussion should read: "It would seem, therefore, that, in weedy fields, common root rot causes even greater damage than in fields comparatively free from weeds, and that, as in Manitoba the percentage of weedy fields is large, the present estimate of loss from common root rot is not too high."

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FIELD TESTS OF THE DIFFERENTIAL REACTION OF WHEAT VARIETIES TO ROOT ROT[1]

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The annual reduction in yield of wheat in Western Canada from the root-rotting fungi *Helminthosporium sativum* P. K. & B., *Ophiobolus graminis* Sacc., and *Fusarium* spp., presents plant pathologists and plant breeders with an important and difficult problem to solve. It is also true that unless the symptoms of these diseases are pronounced in the field, many wheat growers, as well as others, often minimize or entirely overlook the actual damage present. Certain crop sequences and cultural practices have been found very valuable in reducing the loss from root rots, but as these measures are not always entirely effective under all conditions it is generally agreed that a combination of greater varietal resistance in conjunction with the recommended cultural practices would offer the best possible solution of the problem. However, in securing varieties having greater resistance, we are at once faced with the fact that none of those grown in Western Canada are immune, and all are more or less susceptible to the pathogens mentioned. Moreover, in subjecting the varieties to a resistance test under field conditions we must recognize racial differences in virulence of the pathogens, and allow for the effect of reaction to climatic and other environmental soil factors on both pathogen and host. Of these, the effect of drought in obscuring the real disease reaction of the plant is one of the most important difficulties encountered.

The purpose of this paper is to present some of the data already obtained in tests for varietal resistance to the root-rotting fungi and to discuss related problems based on observations during 13 years.

MATERIALS AND METHODS

The plantings were made at Edmonton on a black loam in which root rots are known to develop well. The rows were 12 feet in length, 6 inches apart, and were replicated 4 times along a range 180 feet in length. When the study was begun in 1929, separate tests for varietal resistance to *O. graminis*, *H. sativum*, and *F. culmorum* W. G. Sm., were attempted by means of artificially infesting fallowed soil with the pathogens. However,

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as practically no infection resulted in the case of *O. graminis*, and often too severe seedling mortality in the cases of *H. sativum* and *F. culmorum*. these attempts were abandoned in 1932, and the method of natural soil infestation of all three pathogens mentioned, as favoured by continuous cropping to wheat, adopted. Two methods of artificially infesting the seed bed with *O. graminis* were used, namely, inoculum grown on sterilized oat hulls *(a)* incorporated with the soil before seeding, and *(b)* added with the seed. These two methods were also used in the case of *H. sativum* and *F. culmorum*, and, in addition, the technique of adding a spore suspension to the seed was employed. However, with the naturally infested seed-bed method, it was not until 1937 that a satisfactorily effective level of infestation was reached, and, therefore, all the work prior to this date was essentially of an exploratory nature, and the details are not included in this report. The infection rating data presented in this paper are indicative of the root-rot complex as caused by the various pathogens in a naturally infested soil.

One hundred seeds per 12-foot row were planted, with a belt seeder at a depth of 2 inches. Marquis wheat was planted every tenth row as a guide in estimating the amount of heterogeneity in the experimental area. The planting dates varied, but the mean date was about May 1. Notes were taken within 10 days prior to maturity by cutting crowns longitudinally and estimating disease severity on a percentage basis according to the relative degree of lesioning present in the crown tissue, and by an examination of the lesioning present in other parts of the root system, including the primary and secondary roots and the subcoronal internode. That is to say, the identification of inherent resistance was based wholly on actual disease symptoms, and not on the yielding ability of the variety. Obviously the latter quality would include many factors other than disease resistance. Since the method indicated of securing data is unavoidably somewhat qualitative, and based on personal judgment, it is necessary that the same observer take the notes each year.

There are various opinions as to the best way of estimating disease severity by the examination method (3). Although 11 classes of infection, varying from 0–10, were used in this study, a smaller number of classes would also give good comparative results. The number of plants to be observed from each plot, and the question of using the mode or the mean of the infection-classes are also moot points.

The importance of the factor of different dates of maturing of the varieties was appreciated, and experiments designed to accentuate the importance of this point are included.

EXPERIMENTAL RESULTS

A. Reaction of Wheat Varieties to Root Rots

Out of a total of 148 varieties and selections of spring-habit wheat tested for resistance from 1929 to 1941, the results from only 80, which

are listed with the infection ratings in Table 1, are given in this report. The others, which were discontinued by 1937, because they seemed to have no appreciable resistance, are listed below:

Bobs (Wylers)
Calcutta D_2B
Calcutta O-929-B
Ceres (Brandon)
Ceres (U. of A.)
C-25-13.5 (Brandon)
C-25-145.2 (Brandon)
C-25-85.1 (Brandon)
C-25-424.6 (Brandon)
C-26-12.3 (Brandon)
C-26-36 (Brandon)
C-26-44.7 (Brandon)
C-26-48.2 (Brandon)
C-26-58.2 (Brandon)
C-26-59.2 (Brandon)
C-26-153.15 (Brandon)
C-26-387.42 (Brandon)
C-26-703.7 (Brandon)
Crown × Prelude 932A
Duchess (Ott. 933)
Early Triumph
Forward
Garnet (Brandon)
H-44-24 × Marquis C.T. 127
Heines Kolben
Hope (U. of A.)
Hope—N.D. (Dickinson)
Hope—N.D. (Mandan)
Horning's grüne Dame
Huron (Cap Rouge)
I-28-61 U. of A.
Janetzke's
Khapli
Kitchener (Wheeler)
Kota (673)
Kota × Ruby II-19-19
Kubanka
Lohmann's galizischer Kolben
Manscholt's van Hock
Marquillo
Marquillo × Kanred
Marquis (McKay)
Marquis (Parker)
Marquis (Criddle)
Marquis (Brandon)
Marquis (Ott. 15)
Marquis × Kanred II-17-4
Marquis × Kanred B_9-14
Marquis × Iumillo II-15-43
Marquis × Iumillo II-15-51
Marquis × Iumillo II-15-54
Marquis × Prelude 928E
Pentad (Winnipeg)
Quality
Quality A
Red Fife (Sask. 73)
Red Fife × Downy Riga 642A
Red Indian × Common Emmer 45B
Red Quality A
Red Quality C
Reward (Ott. 928)
Reward (Brandon)
Ruben
Strube's roter Schlanstedter
Svalof's Diamant
Szekacs
Topaz
Vernal.

TABLE 1.—DISEASE RATING OF VARIETIES AND SELECTIONS OF WHEAT USED IN FIELD STUDIES OF RESISTANCE TO ROOT-ROTTING FUNGI FOR 1937, 1938, 1939, AND 1941

No.	Variety*	Disease rating				No.	Variety*	Disease rating			
		1937	1938	1939	1941			1937	1938	1939	1941
		%	%	%	%			%	%	%	%
7	Acme	53	29	34	43	1	Kubanka Ott. 37	56	30	31	34
56	Admiral Yellow × Early					12	Little Club	32	27	31	39
	Sonora	61	36	28	43	38	Major	50	36	28	41
33	Alberta 3	68	47	34	44	10†	Marquis U. of A.	54	40	33	43
57	Apex	64	47	35	45	53	Marquis × Kanred B_2-5	52	40	29	45
8	Arnautka	55	35	30	40	78	Marquis × Iumillo				
43	Aurora	62	27	31	42		II-15-55	55	39	28	39
58	Axminster	49	36	30	41	46	Master	70	49	37	41
62	Bishop	52	41	32	48	48	Minburn	46	38	35	43
65	Blue Ribbon	38	31	31	39	6	Mindum	53	34	37	43
39	Brownie	61	35	44	46	68	McMurachy's C.T. 901	—	35	29	37
82	Caesium	41	33	19	44	32	O.A.C. 35	50	31	28	34
16	Canus	37	41	24	41	4	Peliss	47	29	29	38
17	Ceres	53	47	30	48	5	Pentad	59	39	31	45
66	Ceres × (Hope ×					55	Pentad × Marquis C.T.				
	Florence) C.T. 801	—	39	29	33		120	67	49	40	52
72	Ceres × Reward C.T. 215	—	—	33	—	84	Perages	26	15	20	27
31	Chelsea	56	37	33	48	35	Pioneer Ott. 195	52	36	27	42
45	Crown	55	38	40	36	64	Piper	43	38	37	44
67	Crown × Prelude O-940-A	68	49	38	45	23	Prelude Ott. 135	57	47	29	44
79	Double Cross (825.2)	46	33	26	43	29	Preston	52	33	22	40
71	Downy Riga × Calcutta					47	Producer 45F	39	37	32	40
	553A	72	47	32	46	34	Prospector	65	43	36	46
74	Early Prolific	51	37	32	42	76	Pusa	68	36	26	54
63	Early Red Fife Ott. 16	44	35	38	42	15	Red Bobs 222	64	45	35	49
44	Early Russian Ott. 40	56	40	37	44	22	Red Fife	30	29	24	39
14	Garnet Ott. 652	58	36	30	45	49	Red Fife × Smooth Spelt				
75	Golden	50	40	28	41		686A	46	40	32	43
28	H-44-24	69	44	25	40	41	Red Indian × Common				
89	H-44-25 × Double Cross						Emmer Ott. 434	45	22	29	41
	× Marquis C.T. 303	68	40	32	45	73	Red Russian	53	36	34	39
87	H-44-24 × Double Cross					26	Renfrew	47	40	25	41
	× Marquis C.T. 305	66	30	27	41	69	Renown	70	47	34	42
85	H-44-24 × Reward C.T.					13	Reward U. of A.	60	41	33	50
	118	55	34	29	38	19	Ruby Ott. 623	62	35	23	40
86	H-44-24 × Reward C.T.					11	Speltz-Marz	65	35	32	43
	108	74	42	34	46	59	Supreme	57	49	31	47
27	Hope	63	37	24	43	36	Swedish	31	36	35	44
88	Hope × Reward C.T. 207	76	42	25	43	61	Swedish O-880-D	47	48	38	45
21	Huron Ott. 3	41	34	23	42	37	Tartan	36	30	29	41
81	I-28-46 U. of A.	56	42	25	42	83	Thatcher	69	46	26	42
2	Iumillo	62	40	23	38	18	White Fife Ott. 11	30	30	27	40
3	Kahla	48	30	28	40	77	White Head	47	30	31	42
24	Kitchener	56	31	27	38	51	White Russian D	42	28	24	33
25	Kota	44	30	19	37	52	Yellow Fife × Omega				
54	Kota × Ruby II-19-18	43	49	37	44		Gehun Ott. 482B	63	49	31	42

† Marquis used as control every tenth row.
* The numbers opposite the varieties designate them in Tables 2, 4, 5, and 6.

The infection data, as based on readings on 20 plants per row and 4 replicates, are summarized in Table 2 for the seasons 1937, 1938, 1939, and 1941. Data for 1940 were not secured. In the table the variety number appears opposite the observed percentage infection ratings as found for each year. It will be noted that the range of infection ratings in 1937 was much wider than in the other three seasons, and that the degree

TABLE 2.—THE DISEASE RATING IN PER CENT OF 80 VARIETIES AND SELECTIONS OF WHEAT* TO ROOT-ROTTING FUNGI UNDER FIELD CONDITIONS. THE VARIETIES ARE GROUPED ACCORDING TO AVERAGE INFECTION RATING DURING EACH OF FOUR YEARS OF TEST.

%	1937		1938		1939		1941	
19						25 82		
22				41	A	29		
23						2 19 21		
24						16 22 27 51		
25			A			26 28 81 85		
26					B	20 76 79 83		
27				12 43		18 24 35 87		
28				51		3 32 38 42 56 75 78		
29				4 7 22		4 23 37 41 53 66 68 85		
30		18 22		1 3 18 25 37 77 87		8 14 17 58 60		
31		36		24 32 65	C	1 5 12 30 43 52 59 65 77		
32		12	B			11 47 49 62 70 71 74		
33				29 79 82		13 31 72		51 66
34	A			6 21 85		7 33 40 50 69 73 86		1 32
35				8 10 11 19 39 63 68		15 36 48 57	A	
36		37		14 35 36 38 42 56 58 73 76	D	10 34		
37		16	C	27 31 47 74		6 44 46 54 64 80		25 68
38		65		40 45 48 64		61 63 67		2 4 24 85
39		47		5 66 78				12 22 65 73 78
40				2 26 44 49 53 75 89		45 55	B	3 8 18 19 28 29 47
41		21 82		13 16 20 30 50 60 62				10 16 26 37 38 41 46 50 58 70 75 87
42		51	D	81 86 88	E			21 35 43 52 63 69 74 77 81 83
43		54 64		34			C	6 7 11 20 27 30 40 42 48 49 56 79 80 88
44	B	25 63		28		39		23 33 36 44 54 64 82
45		41		15				5 14 53 57 60 61 67 89
46		48 49 79		83				34 39 45 71 86
47		4 26 50 61 77	E	17 23 33 57 69 71				59
48		3 10 60		61			D	17 31 62
49		58		46 52 54 55 59 67				15
50		32 38 75						13
51		40 74						
52		20 29 35 53 62					E	55
53	C	6 7 17 73						
54								76
55		8 45 78 85						
56		1 24 31 44 81						
57		23 30 59						
58		14						
59		5						
60		13 70						
61		39 56						
62	D	2 19						
63		27 52						
64		15 57						
65		11 34						
66		87						
67		55 80						
68		33 43 67 76 89						
69		28 83						
70	E	46 69						
72		42 71						
74		86						
76		88						

* See Table 1 for varieties represented by these numbers.
A, B, C, D, and E are infection categories, each comprising one-fifth of the yearly total range of infection.

or percentage of infection varies from year to year rather markedly. Climatic conditions are undoubtedly responsible for these differences. In Table 3 are shown rainfall and temperature data. It must be admitted that these weather data do not present a complete picture. Much more detail would be required to indicate important factors such as soil moisture and temperature at planting time, timeliness of rain storms, and relative evaporation losses. The influence of weather on root rot is discussed in a paper (4) published since the present article was prepared.

TABLE 3.—CLIMATIC DATA AT EDMONTON DURING MAY, JUNE, AND JULY FOR YEARS 1937 TO 1942, INCLUSIVE

Year	Average Temperature, °F.							Rainfall		
	Soil				Air			May	June	July
	Seeding	May	June	July	May	June	July			
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	in.	in.	in.
1937	47	46	58	60	54	60	63	1.7	0.9	8.3
1938	51	52	63	71	51	61	64	1.4	4.7	3.2
1939	50	51	55	64	53	53	63	5.4	1.8	1.5
1940	42	53	56	58	55	57	61	2.6	2.5	3.7
1941	57	54	62	69	51	61	68	0.9	4.9	1.1
1942	36	39	53	67	51	56	63	1.5	8.5	3.4

The classification of the varieties according to their susceptibility to root rot in each year falls more or less smoothly into normal distribution curves, indicating the existence of what seem actual differences in resistance. The grouping into categories based on the range of infection-percentages is shown by the letters A, B, C, D, and E, dividing the range as nearly as possible into 5 equal parts. In any particular season these 5 divisions may be regarded as placing the varieties in a range of their relative susceptibility to root rot. Theoretically, it might be assumed that each variety would fall into the same category each year. Although this was not the case with all varieties, yet, in carefully reviewing the placements for the four seasons, it was found that some varieties consistently occurred in the lighter infection groups. Twenty-five of the varieties consistently grouped in the light infection classes were selected for further tests. These were arranged in lots of 5, in descending order of resistance. In addition, another control lot of 5 was selected as showing neither marked resistance nor susceptibility. Incidentally, this group includes some of our most commonly grown varieties of spring wheat.

In 1942 the 30 varieties were planted in 12-foot rows 1 foot apart and replicated 6 times. Seeding was on May 5, and notes were taken on August 20 and 21, before any of them had matured. The estimated time before maturity varied from 4 to 10 days for the different varieties. The infection rating data appear in Table 4.

During the 1942 season conditions were favourable for growth, with an abundance of rainfall well distributed throughout the entire growing season. Owing to the fact that the disease rating was purposely made somewhat earlier than usual, it was fairly light, with a percentage range from 14 to 31. The effect on infection rating of taking these data earlier is discussed in section B. Other factors that tended to decrease infection rating were the inclusion of the more resistant varieties in this test, and the effect on the pathogens of the significantly low average temperature of the soil during May and June.

TABLE 4.—INFECTION RATING OF 30 VARIETIES OF WHEAT AS PRODUCED BY ROOT-ROTTING FUNGI UNDER NATURAL FIELD CONDITIONS IN 1942

Variety*		Infection	Variety*		Infection
		%			%
22	Red Fife	22.3	35	Pioneer	17.2
25	Kota	18.8	36	Swedish	24.7
32	O.A.C. 35	14.7	38	Major	17.0
51	White Russian	17.5	47	Producer	16.7
65	Blue Ribbon	16.0	68	McMurachy's	15.2
18	White Fife	17.3	16	Canus	22.8
21	Huron	23.5	58	Axminster	19.7
24	Kitchener	19.7	66	Ceres × (Hope × Florence)	23.0
79	Double Cross	19.5	74	Early Prolific	20.2
82	Caesium	14.7	77	White Head	22.8
1	Kubanka	17.7	10	Marquis	24.5
29	Preston	19.7	13	Reward	31.2
37	Tartan	15.7	15	Red Bobs	26.8
41	Red Indian × Common Emmer	14.3	34	Prospector	24.7
73	Red Russian	16.3	72	Calcutta	27.0

F value for varieties 5.13, 5% point 1.59, 1% point 1.92. Twice S.E. of difference 5.3.
* The varieties are numbered as in Tables 1 and 2.

B. *Effect of Time of Securing Data upon Infection Rating*

It is common observation that root-rot symptoms, especially on the crown of the wheat plant, become more marked as the plant approaches maturity. Also, in the mature plant the problem of securing an accurate estimate of the root-rot damage becomes very complicated, because, in the ripening-off process, the basal parts take on a colour not unlike that associated with infection. An attempt to demonstrate this point was made in 1941. Fifteen varieties, differing in their reaction to root rot, were selected for the purpose indicated. These were seeded in 4 replicates, on land alternately in wheat and fallow in 12-foot rows, 6 inches apart. Twenty plants were rated for infection at two periods, namely, July 26, when the

plants were in the soft dough stage, and August 20, which was the approximate date of maturation of all the varieties. The infection ratings are presented in Table 5, where each variety has the number used to designate it in Tables 1 and 2.

The infection ratings at the first reading were all quite light, the lowest being 5% and the highest 17%. At the second reading the lowest average rating was 17% and the highest 40%. This range is less than that of the same varieties grown on the continuous wheat plot, as shown in Table 2, for 1941. Planting wheat alternate seasons with fallowing is known to reduce root rot, hence the difference observed was to be expected.

TABLE 5.—INFECTION DATA INDICATING THE TENDENCY OF SYMPTOMS PRODUCED BY THE ROOT-ROTTING FUNGI TO INCREASE AS THE WHEAT PLANT NEARED MATURITY IN 1941

Variety*		Average infection rating		Relative order of Susceptibility	
		July 26	Aug. 20	July 26	Aug. 20
		%	%		
5	Pentad	8.2	25.0	3	5
12	Little Club	5.0	17.0	1	2
13	Reward	15.4	40.4	14	15
16	Canus	9.0	25.0	6	6
28	H-44-24	13.1	31.6	13	10
33	Alberta 3	17.0	37.6	15	14
36	Swedish	8.4	26.2	4	7
43	Aurora	10.4	32.0	9	11
44	Early Russian	8.5	27.2	5	8
46	Master	11.1	33.5	11	13
52	Yellow Fife × Omega Gehun	11.1	21.9	10	4
53	Marquis × Kanred	11.7	33.4	12	12
73	Red Russian	9.1	15.0	7	1
77	White Head	7.7	19.0	2	3
10	Marquis	9.5	31.4	8	9

* The varieties are numbered as in Tables 1 and 2.

The increase in infection percentages between the two dates of recording was marked in the case of all varieties. The relative position of each variety as regards infection at the two readings changed but little, as may be seen from the table. A number of the varieties were the same as those used in the 1942 test, cited in section A (Table 4), and their resistance is again indicated in this test.

In 1942 an additional planting was made to determine the effect of obtaining the infection rating at different dates. Four replicates of the 30 varieties used in the variety test were planted May 5 on land fallowed in 1941 and previously in wheat for three years. Notes were taken on the roots and crowns of 20 plants from each row on July 27, August 5, and August 17, the last date being 4 to 10 days before maturity. The data appear in Table 6.

TABLE 6.—INFECTION DATA INDICATING THE TENDENCY OF SYMPTOMS PRODUCED BY THE ROOT-ROTTING FUNGI TO INCREASE AS THE WHEAT PLANT NEARED MATURITY IN 1942

Variety*		Average infection rating		
		July 27	Aug. 5	Aug. 17
		%	%	%
22	Red Fife	9.3	15.3	16.3
25	Kota	13.3	17.0	20.0
32	O.A.C. 35	10.0	13.8	17.0
51	White Russian	7.5	15.0	18.8
65	Blue Ribbon	11.3	21.8	18.5
18	White Fife	9.8	16.5	17.8
21	Huron	15.3	12.8	19.0
24	Kitchener	11.8	19.3	19.5
79	Double Cross	13.5	17.5	20.8
82	Caesium	10.5	15.8	21.0
1	Kubanka	12.0	20.0	25.3
29	Preston	11.3	18.0	26.8
37	Tartan	8.3	14.0	18.3
41	Red Indian × Common Emmer	10.8	16.3	19.8
73	Red Russian	14.3	20.8	22.8
35	Pioneer	11.3	18.8	17.0
36	Swedish	13.8	17.3	25.0
38	Major	9.5	16.3	19.8
47	Producer	15.5	19.5	26.5
68	McMurachy's	15.0	15.3	16.3
16	Canus	12.5	15.3	20.3
58	Axminister	12.8	14.3	20.8
66	Ceres × (Hope × Florence)	9.3	18.3	21.0
74	Early Prolific	8.3	13.5	18.5
77	White Head	11.8	16.5	23.8
10	Marquis	13.3	17.0	24.9
13	Reward	11.0	16.8	25.0
15	Red Bobs	10.5	16.0	25.8
34	Prospector	12.5	14.5	25.0
72	Calcutta	14.3	19.5	25.5

F value for totals of varieties 2.19; for age of plant 132.27; 5% point $\frac{1.55}{3.03}$; 1% point $\frac{1.85}{4.68}$

Twice standard error of difference 6.4.

* The varieties are numbered as in Tables 1 and 2.

It is apparent that the symptoms of root rot increased progressively during the month prior to maturity. Therefore, since wheat varieties differ materially in their spans of life, it is obviously necessary to secure infection data on them at the same relative stage of ripening. This would eliminate a certain degree of error encountered in taking notes on all varieties at the same time.

DISCUSSION

The data presented in this study indicate that, in spite of the disturbing influence of seasonal climatic factors on the range of infection from one year to another on the wheat varieties tested, certain ones seem to possess more inherent resistance to the root-rot complex than others (Tables 2 and 3). Some of those appearing to have appreciable resistance are, Red Fife, Kota, O.A.C. 35, White Russian, Blue Ribbon, Huron, Kitchener, Double Cross, Caesium, Kubanka, Red Russian, Swedish, Major, McMurachy's Selection, and White Head (Table 4).

Forster and Croll (2), concluded from the results of an exploratory study on 4 wheat varieties, that natural resistance is more important than the environmental factors, or the ripening behaviour, in influencing the development of lesions on the roots. We agree with this, but wish to emphasize the role of factors other than the inherent resistance of the plant in studies of this nature. For example, drought has been found to markedly influence the final infection rating. Early drought, by destroying portions of the root system, opens avenues not only for the entrance of soil-borne pathogens, but saprophytes as well. Also, drought, towards the ripening stage, causes a discolouration of the crown tissue difficult to distinguish from that associated with infection by the root-rotting fungi. It would appear from these studies that, in general, the inherent resistance of a variety can be more accurately identified from 4 to 7 days just prior to maturation than during the seedling stage or the period intervening. The reason for this is that under field conditions, in naturally infested soil, the maximum development of symptoms occurs just before maturity, although there is a gradual marked increase during the month preceding (Table 5). However, owing to the effect of variable climatic factors, it is not possible to make a general interpretation of this increase on a percentage basis. For example, in 1941 the amount of infection tripled in many cases in a little less than a month, and in 1942 the amounts doubled during a period of 22 days. Even an interval of a week can effect a considerable increase in intensity of symptoms.

Moreover, it is important that the varieties be grouped according to their dates of ripening. That is to say, the various groups that mature at different periods would be planted at the same time so that all varieties would be subject to like conditions during most of the growth period, and each group would be harvested at intervals of three or four days, corresponding to their dates of ripening. The data should be secured by one observer at any one station, as multiple observers necessarily introduce errors of personal judgment in estimating the infection symptoms on a numerical basis. Obviously, this factor would not be important when comparing data from different stations.

With regard to the relative merits of conducting resistance studies in the field versus the greenhouse in naturally infested field soil, the following observations, based on information obtained from these investigations may be outlined. In the greenhouse in pot culture it is fairly easy to secure killing of all seedlings by sufficiently increasing the inoculum, or, by decreasing it, to obtain a very light infection, either of which is not satisfactory. Also, under these artificial conditions the behaviour of the

pathogen tends to be far more erratic than in the field, where the soil microflora has become more stabilized. There is also the fact that seedling material which is obviously unsatisfactory for resistance studies, cannot be brought to natural maturity on account of space and other limitations.

Under field conditions, in naturally infested soil, not only does infection of the host tend to develop more gradually, and also later during the post-seedling stage, but the plants mature fairly normally, which is very desirable. But even here, if inoculum is applied as a spore suspension on the seed, or put into the drill in other forms, severe disease may develop and a high percentage of the seedlings be killed before or shortly after they emerge, and the remaining plants, having less competition, become abnormally vigorous and healthy. Consequently, the difference in numbers of surviving seedlings from an attack of this kind is of doubtful value in indicating the obviously limited natural resistance that a variety may possess. For the reasons mentioned it seems essential that the identification of varietal resistance should be attempted only in the field in naturally infested soil.

Unfortunately, no very outstanding degree of resistance has been discovered yet in this study, nor is such likely to be found, even when all other available varieties have been tested. However, the completion of this study would provide the plant breeder with necessary information for the development of new varieties with greater resistance to the root-rotting fungi.

SUMMARY

A progress report is submitted of the relative resistance during several years of 148 varieties and strains of spring-habit wheat to the root-rotting fungi, *Ophiobolus graminis*, *Fusarium* spp., and *Helminthosporium sativum*, under field conditions, and problems associated with testing for this resistance are discussed. The varieties and strains were found to fall rather consistently into different resistance groups. The studies show that it is very important that data on resistance be recorded from about 4 to 7 days prior to maturity, because, if delayed, the natural differences may easily become indistinguishable. Also, notes should be taken on varieties of different ripening habit at the same relative stage of maturation. The presence of dry soil conditions markedly complicates the interpretation of infection symptoms.

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LEVEL AND SOURCE OF PROTEIN IN POULTRY PRODUCTION

I. AS RELATED TO ECONOMICAL PRODUCTION OF GROWTH IN PULLETS[1]

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Maximum growth in pullets is not necessarily the most satisfactory growth. From a physiological standpoint the greatest body weight in a given time may not mean the production of the most sound individual. Under these conditions moreover, the feeds may not be used as efficiently for the production of gain in weight. In addition, rapid growth may be occasioned at a greater cost in consumption of feed containing high priced ingredients than the value of the increased weight of the bird would merit. Since the production of tissue other than bone in growth is largely a building up of protein materials, the level of protein in the ration becomes a consideration of major importance. Since feeds containing large proportions of protein are the most costly ingredients of the ration the factor of economy of production in growth is very pertinent to a study of the effect of proteins. Another factor related not only to economy, but also to hygiene in rearing, operations, is the supplementation of rations of varying levels of protein by adequate and suitable green range. The experiment herein reported was carried out as a wartime measure to determine to what extent the level of protein in rations could be safely lowered since it was believed that unnecessarily high levels of protein are commonly being fed. It was designed to furnish information on (1) the approximate level of protein which might be expected to give the most satisfactory and economical rate of growth commensurate with efficiency of utilization of feed and available pasture, (2) whether a large proportion of vegetable protein may be substituted for animal protein and at what level of protein feeding, (3) the simplification of feeding methods through the use of scratch grains as a diluent to the higher protein mash portion of the ration, and (4) the effect of the various levels and sources of proteins on subsequent egg production. The last mentioned will be considered in a later paper dealing with the egg production phase of the experiment.

The subject of protein levels and sources for both growth and egg production has been investigated and reported upon by many workers. This work has been reviewed recently by Heuser (1). As a consequence, references to individual work will be made only where pertinent to specific features of the work. It should be stated however, that workers are in general agreement as to maximum and minimum levels of protein, in the former case above which no further appreciable response may be expected and in the latter instance below which development is seriously retarded. Agreement is not so marked, however, with intermediate levels and with

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the balance between maximum growth, efficiency and economy. Supplementation under practical conditions by pasture, and simplicity of feeding methods have also usually not been considered in connection with protein levels.

EXPERIMENTAL

Six paddocks which had been in grass sod for some years were selected for the rearing phase of this experiment. Sexed, day-old Barred Rock pullets were randomized into 6 lots and reared in 10′ × 12′ movable colony houses, approximately 100 pullets to the group. The hatch was taken off May 15, making these chicks somewhat later hatched than usual for the area. The chicks were first allowed out on grass 18 days after hatching. Since each paddock measured 90′ × 80′ there were approximately 70 square feet per pullet equivalent to a rate of 600 birds to the acre. This rate represents approximately 25% heavier pasturing than is usually recommended. Actually a relatively dry summer was experienced and the green cover suffered accordingly, with the result that the experiment constituted a rather severe test of the ability of pullets to utilize low protein rations satisfactorily with only a limited opportunity for supplementation by consumption of fresh grass.

TABLE 1.—INGREDIENTS OF THE MASHES USED, WITH CHEMICAL ANALYSES

	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
	lb.	lb.	lb.	lb.	lb.	lb.
Wheat bran	15	15	15	15	15	15
Wheat shorts	15	15	15	15	15	15
Ground Oats	15	15	15	15	15	15
Corn starch	40	33	27	37	28	19
Meat meal (60%)	2	4	6	—	—	—
Fish meal (70%)	3	6	9	—	—	—
Skimmilk, dried	2	4	6	5	5	5
Soy bean meal	—	—	—	4	12	20
Dehydrated alfalfa leaf meal	6	6	6	6	6	6
Ground oyster shell	1	1	—	1	1	1
Bone meal	—	—	—	1	2	3
Salt	½	½	½	½	½	½
Cod liver oil (1850 A - 400 D)	½	½	½	½	½	½
Total	100	100	100	100	100	100
	%	%	%	%	%	%
Moisture	10.10	9.65	9.48	10.20	9.55	9.65
Protein	12.45	15.95	20.14	11.25	15.37	20.09
Fat (ether extract)	3.00	3.35	3.33	3.20	3.33	3.70
Ash	4.80	6.20	6.55	4.68	6.20	6.98
Crude fibre	4.97	6.19	5.58	5.16	6.80	6.82
N-free extract	64.68	58.66	54.92	65.51	58.75	52.76
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calcium	1.025	1.239	1.194	0.935	1.234	1.557
Phosphorus	0.643	0.718	0.974	0.595	0.819	1.200

The paddocks were paired according to experimental treatment, one of each pair having the same level of supplemental proteins from animal and the other from vegetable sources. In the case of the latter, however, 5% of the supplemental protein of the mash mixture was from skim milk powder fed largely as a source of B vitamins but also with the object of supplementing the amino acid deficiencies of the vegetable protein source. Since it was desired to use mashes as low as 12% in protein, a level approximately that of common grains, while at the same time having appreciable quantities of animal or vegetable protein supplements in the mashes, it was necessary to use a feed source free of protein. Consequently corn starch was used as a diluent for this purpose.

The chemical analyses of the mashes fed are shown in Table 1.

It will be noted that in the above rations the basal portion of the mash made up a constant proportion of the ingredients in all instances, the variables being the animal or vegetable protein feeds and the corn starch. Also from level to level the proportion of the different animal feeds was constant even though their gross amounts varied in keeping with the required protein level. It was necessary to vary ground oyster shell and bone meal in order to maintain similar and adequate levels and ratios of calcium and phosphorus. With the exception of the low protein group, close agreement exists between levels of protein for the vegetable and animal protein mashes. The level of riboflavin was adequate in all mashes.

It should be noted that after the birds were out on green range in the sunshine the cod liver oil and dehydrated alfalfa leaf meal were omitted from the mash since they were no longer required and added substantially to the cost of the ration.

In keeping with one of the main objects of the experiment, the determination of economical levels of protein with maximum simplicity of adjustment of protein levels when required, the mashes set forth above were fed with scratch grain according to the following schedule:—

1 – 7 weeks inclusive—mash only	
8 – 10 weeks inclusive—4 parts mash	1 part grain
11 – 13 weeks inclusive—3 parts mash	1 part grain
14 – 16 weeks inclusive—2 parts mash	1 part grain
17 – 19 weeks inclusive—1 part mash	1 part grain
20 – 22 weeks inclusive—1 part mash	2 parts grain
23 – 24 weeks inclusive—1 part mash	3 parts grain

The protein levels actually consumed considering both grain and mash of the above schedule and exclusive of the small and unmeasurable amount obtained from pasture are shown in Table 2.

The scratch grain used in this experiment was a commercial mixture containing wheat, cracked corn, oats, barley, buckwheat, sunflower seed and milo maize, which analysed 12.93% of protein. It will be noted from the above table that the level of protein actually consumed throughout the test was 12.66%, 14.69% and 17.13% for the animal protein groups and 12.00%, 14.34% and 17.02% for vegetable protein.

TABLE 2.—LEVEL OF PROTEIN ON BASIS OF ACTUAL CONSUMPTION

	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
1 - 7 weeks inclusive	12.45	15.95	20.14	11.25	15.37	20.10
8 - 10 weeks inclusive	12.55	15.35	18.70	11.60	14.88	18.67
11 - 13 weeks inclusive	12.57	15.19	18.34	11.67	14.76	18.31
14 - 16 weeks inclusive	12.61	14.94	17.74	11.81	14.56	17.71
17 - 19 weeks inclusive	12.69	14.44	16.53	12.09	14.15	16.52
20 - 22 weeks inclusive	12.77	13.94	15.33	12.37	13.74	15.32
23 - 24 weeks inclusive	12.81	13.68	14.73	12.51	13.54	14.72
Average*	12.66	14.69	17.13	12.00	14.34	17.02

* Weighted on the basis of actual consumption.

All birds were weighed individually weekly and the feed weighed back to obtain figures for feed consumption. The criteria used to determine the comparative efficiency of the different treatments were body weight, feed consumption, mortality, and cost of rearing.

Throughout this report the term vegetable protein is used to designate those groups whose supplementary protein was largely supplied by soy bean meal. On a basis of actual consumption the animal feed (dried skim milk) made up 2.8% of the total feed intake on the average for all vegetable protein rations, i.e. 1% of the protein intake was from an animal source. During the more critical period of the chicks growth, from 1 to 7 weeks, the figures were 5% and 1.75% respectively.

RESULTS

The growth data obtained during the whole rearing period are graphically presented in Figure 1, while all the pertinent information for 24 weeks of age is summarized in Table 3.

TABLE 3.—BODY WEIGHT AT 24 WEEKS AND CONSUMPTION OF FEED AND PROTEIN

Protein source and level	Mean level of protein	Body weight	Average feed consumption per bird	Average protein consumption per bird
	%	gm.	gm.	gm.
Low animal	12.66	1904	1385	175.4
Medium animal	14.69	2073	1404	206.3
High animal	17.13	2193	1556	266.5
Low vegetable	12.00	1751	1383	165.3
Medium vegetable	14.34	2067	1831	262.1
High vegetable	17.02	2145	1681	286.1

Body Weight as a Function of Age

In Figure 1, actual mean body weight in grams is plotted against age in weeks. An opportunity is thus given to compare rate of growth during the whole growing period to 24 weeks of age at which time the most mature birds of the high and medium animal protein groups were laying their first eggs. It is immediately obvious that the level of protein for the low protein groups was insufficient, since almost from the start of the experiment their body weights were very much and significantly lower than those of all other groups. This discrepancy, rather than decreasing with age as might be expected on the basis of a presumed lower requirement of

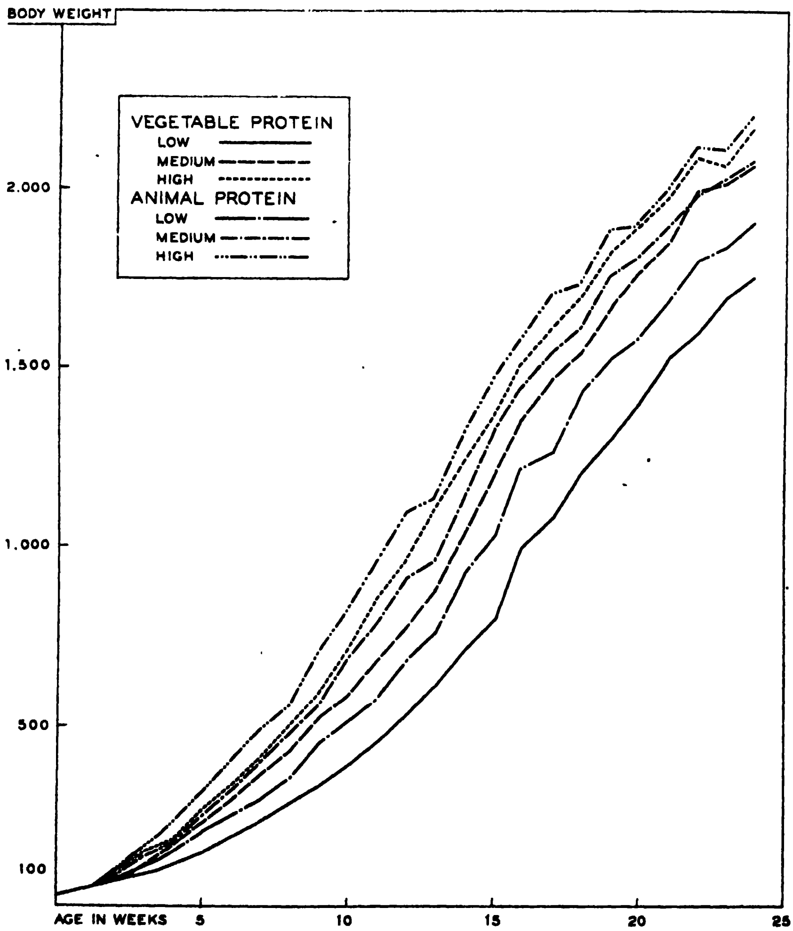

FIGURE 1

protein with advancing age and reduced rate of growth, actually increases. At 40 weeks of age the low vegetable and animal protein groups were of equal weight and some 160 grams lighter than the other groups indicating that the depressed growth of the rearing period was evident through the period of egg production. The high protein groups also grew at a significantly more rapid rate during the greater part of the rearing period than

the medium protein groups although the differences were relatively small in a practical sense, the greatest difference at 24 weeks being 120 grams per bird. Differences between animal and vegetable protein were significant at the low protein level only, which might argue a more marked deficiency in the vegetable protein when fed at a borderline level or might be due to a slightly higher level of protein in the low animal protein ration or to a combination of both factors. It was noted at the conclusion of the rearing phase of the test that the medium animal protein group, though 120 grams lighter in weight than the high animal protein group, was as well developed sexually as indicated by general observation of the groups for comb development and by the fact that slightly more birds were in production at 24 weeks of age. The vegetable protein groups were definitely less mature sexually at this age.

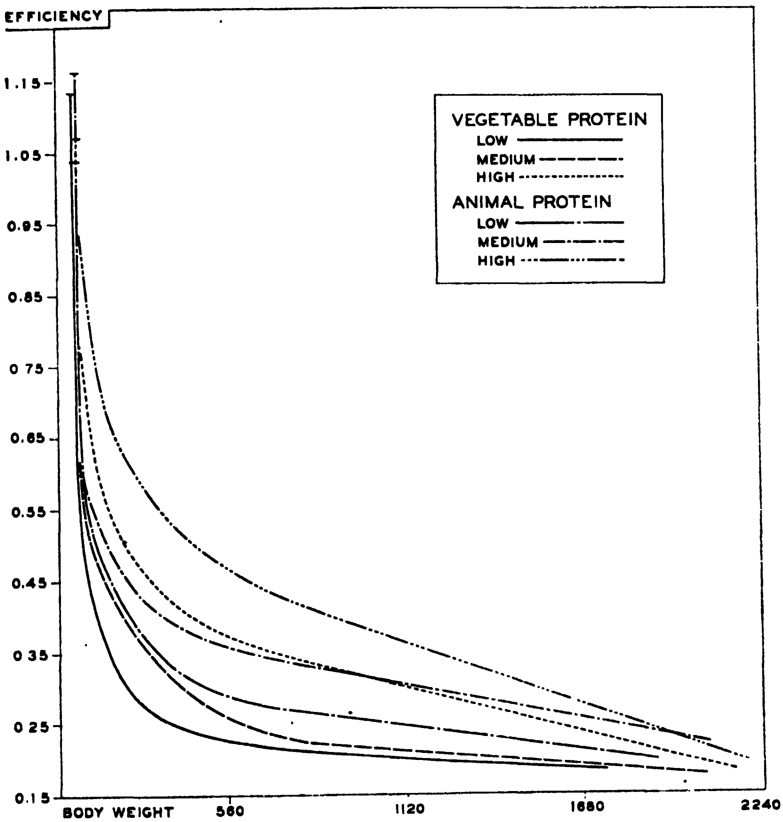

FIGURE 2.

Efficiency of Use of Feed and Protein

The amount of feed or protein required to bring a pullet to any given weight is an important factor in that it indicates the efficiency of use of feed or protein for the maintenance of body weight and the production of gain. Efficiency is usually expressed as a ratio between gain and feed consumed, indicating the gain produced per unit of feed consumed or vice

versa. Since the feed used for gain and for maintenance of the body cannot be separated it is preferred to express efficiency as body weight ÷ the feed consumed to attain that body weight, including that for both gain and maintenance. If efficiency, thus calculated, is plotted against age a fallacious interpretation may result in that the most efficient group at any age may be much smaller in actual weight than other groups; a fact which is not shown in the curves thus plotted; at the same body weight, which would require a longer period of growth for the lighter group, the efficiency would probably be very markedly reversed. For this reason both feed and protein efficiency were plotted against body weight. Since the protein levels were changed periodically according to a set plan, as previously indicated, the live weight to feed relationship does not conform

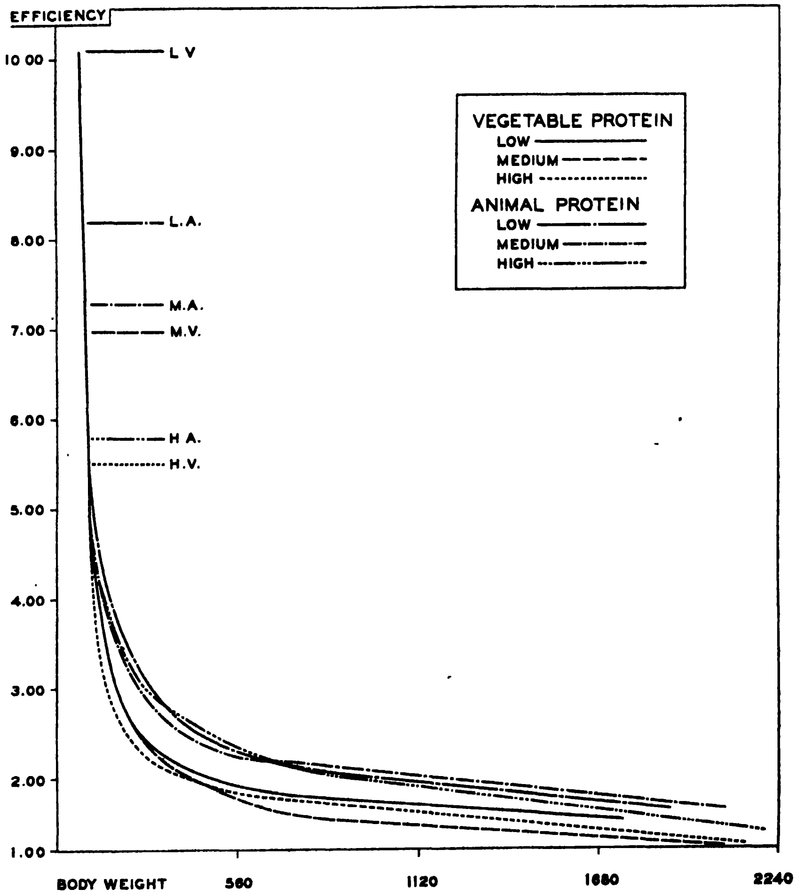

FIGURE 3

to the curve of the law of diminishing increment, consequently the Spillman equation and the equation for a straight line derived therefrom as used by Titus (3) and Hammond *et al.* (2) are not strictly applicable to these data. Figure 2 shows efficiency as derived from the ratio between body weight and cumulative feed plotted against body weight. Figure 3 shows similar information for protein.

A consideration of Figure 2 shows that the group fed high animal protein was more efficient in the use of feed than any other group, followed by those on medium animal protein and high vegetable protein which do not differ significantly. Low animal protein and medium and low vegetable protein were relatively inefficient.

Since one group could be more efficient in its use of feed but less efficient in its use of protein because of a higher level of protein in its feed, the protein efficiency in relation to body weight must also be considered. Figure 3 indicates that protein efficiency actually did not parallel efficiency of feed. The greatest efficiency, particularly at the higher body weights, was attained by the medium and low animal protein groups followed by the high animal protein group. The vegetable proteins were definitely less efficient in this respect than the animal proteins.

Mortality

Mortality of pullets exclusive of what may be termed incubator mortality, that is, deaths during the first 2 or 3 days, before the feeding treatment could possibly have any effect, and of several accidental deaths was as follows:

	Animal Protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
Original number	100.00	98	97	95	93	92
Deaths (to 24 wks.)	14	2	6	15	27	14
Percentage mortality	14.00	2.04	6.19	15.79	29.03	15.22

As far as could be ascertained by autopsy and by observation, no conditions of an epidemic nature were encountered and most of the mortality was from birds which developed poorly and subsequently died or were killed because of a hopeless condition. The medium vegetable protein must be excepted from the above statement since a very high mortality was experienced during the second week from an unexplained cause, considered to be probably due to a management factor. If these deaths are excepted, a mortality of 14.29% was experienced by this lot which is in line with that of the other vegetable protein groups. The effect of this environmental disturbance was reflected also in the efficiency of the group due to abnormally high feed consumption as can be noted from Figure in and for this reason little weight is placed on the data from this group 3, relation to comparable levels and sources. It may be safely assumed, although comparisons of mortality are difficult, that the mortality was significantly lower on the medium and high animal protein levels than on the low level. It would also seem reasonable to assume on the basis of these data that a higher mortality may be expected with protein from a vegetable rather than an animal source.

Relative Economy of Different Levels and Sources of Protein

In the final analysis the cost of rearing of the mature pullet is a most important consideration. This has been calculated, covering feed costs only, on the basis of current feed prices and is shown to 24 weeks and per pound of bird at 24 weeks of age (Table 4).

TABLE 4.—FEED COSTS IN REARING TO 24 WEEKS OF AGE

	Per bird	Per pound
	cts.	cts.
Animal proteins		
Low	33.11	7.89
Medium	36.32	7.95
High	41.88	8.65
Vegetable proteins		
Low	34.56	8.95
Medium	47.11	10.34
High	44.28	9.36

Protein supplements—meat meal (60% prot.) \$3.25 cwt.; fish meal (70% prot.) \$3.60 cwt.; soy bean meal \$2.35 cwt.; skim milk powder \$7.75 cwt.

Feed costs to 24 weeks are decidedly in favour of the lower protein levels. Since the weights at 24 weeks varied greatly a more critical test of economy is the comparison per pound of live weight produced. In spite of the smaller cost of the lower protein rations the greater increase in weight at the higher levels made the cost per pound very similar. Actually the cost per pound of pullet on the low animal protein ration is 99% of that on the medium protein whereas the cost of the latter is 92% of that of the high protein ration. That is to say nothing is to be gained in economy by using the low protein ration, whereas a saving of 8% could be made by using the medium protein ration rather than the high protein one. Considering vegetable proteins the low protein ration had a cost of 96% of the high protein ration, a relatively small difference. The cost of the medium vegetable ration is entirely out of line with expectation due to factors previously stated under the heading of mortality. It should be noted that where mortality is reduced to terms of economic loss the low protein level and the vegetable source suffer still further by comparison.

DISCUSSION

On the basis of weight attained at any given age these data indicate the low protein levels to be inadequate. A considerably lower body weight at 24 weeks combined with a much longer rearing period as indicated by degree of sexual maturity at that time seriously interferes with the opportunity for economical production of eggs. This is particularly true when considered in the light of the very great effect of days to first egg on annual production of eggs. Between high and medium levels of proteins on the

other hand, body weight differences, although significant, were of small practical value. Differences between the animal and vegetable protein groups were consistent but relatively unimportant.

Efficiency, as indicated by the body weight produced per unit of feed was definitely superior for the high animal protein group followed by the medium animal and high vegetable groups which were approximately equal. Efficiency of the remaining groups was relatively low. On the basis of actual protein intake, however, the medium animal protein group was outstanding, followed by high and low animal protein groups. The vegetable protein groups were relatively low in protein efficiency.

For actual and efficient production of body weight, therefore, the high and medium levels of animal protein are outstanding with only the high vegetable protein in a similar range of quality.

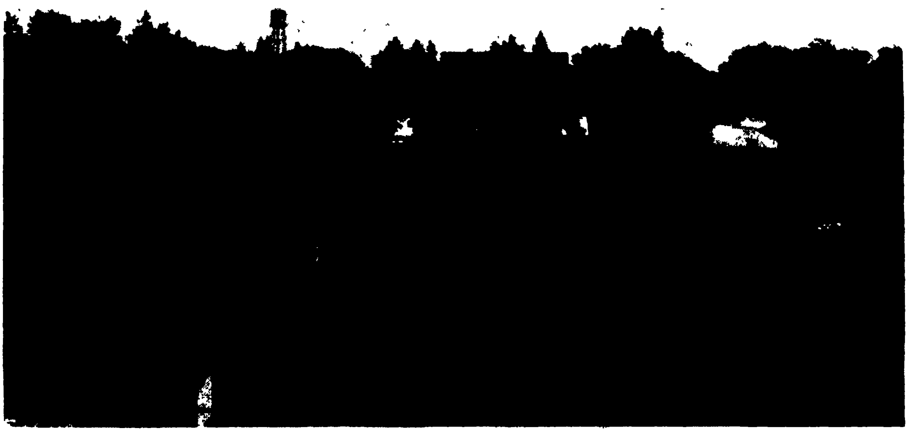

FIGURE 4. Severity of pasturing—paddocks of low, medium and high animal protein groups left front to back and low to high vegetable groups right front to back—dark patches, reseeding with alfalfa.

Mortality definitely favoured the medium and high animal protein groups. All the vegetable and the low protein animal groups were quite high in mortality. The economic importance of this factor is very great since with each death the original cost of the chick plus the feed to raise it to time of death is complete loss.

Feed cost per pound of pullet raised to 24 weeks of age differs by approximately 1% between medium and low levels but by 8% between medium and high thus making an appreciable balance in favour of medium animal protein. In spite of the lower cost of vegetable protein rations their cost per pound of bird produced was greater than that of the animal protein groups.

On the very low levels of protein used in this experiment, any supplementation to the ration which the birds were able to make through use of the available pasture was not sufficient to bring their ration to the level of the higher protein rations in efficiency. Where medium levels of protein were fed, however, the level of protein given plus the herbage consumed produced almost as rapid growth and a similar or even slightly superior efficiency of use of protein. That this supplementation was a factor is shown in a very interesting contrast of the state of the pasture in mid-summer as shown in Figure 4.

It is quite apparent that the high animal protein ration required little if any supplementation and it was observed that these pullets did not pasture the grass to any extent. The medium animal protein group pastured their paddock intensively, and the low protein more so. It was also observed that all moulted feathers were picked up and consumed in the low animal and vegetable protein groups but not in the others. The paddocks of the vegetable protein groups appear to be more intensively pastured than those of the animal protein group. A decided contrast between the same levels of animal and vegetable protein is evident in the top two paddocks (high levels of protein). It seems obvious that even the high vegetable protein ration was inadequate. In this connection it should be reiterated that the rations of all groups were balanced with respect to all known factors other than protein.

Since in this experiment medium animal protein gave practically equal growth and greater protein efficiency than high animal protein these birds apparently were able to make up their deficiency, if any existed, through utilization of their pasture. A greater area for pasturing and/or a season of greater rainfall without doubt would have made this supplementation complete.

SUMMARY

Six groups of approximately 100 pullets each were raised under closely identical conditions and fed rations comparable in all known respects excepting level or source of protein. The following observations are made as a result of this study.

1. Pullets which received 17% protein from either a vegetable or animal source during 24 weeks of growth attained significantly greater body weights on the average at that age than did pullets on rations containing 14.5% or 12.5% of protein. The differences between the higher levels were small, the greatest being 5.5%. Each of the higher levels proved considerably more satisfactory than the 12.5% levels. At all levels, animal protein was significantly more efficient on the average than vegetable protein, but, with the exception of the lowest level, these differences were small.

2. On the basis of efficiency of utilization of the ingested protein per unit of body weight produced, the 14.5% animal protein ration was slightly superior to the 12.5% and to the 17% to an even greater degree. The vegetable protein rations were decidedly inferior to the animal protein in efficiency.

3. Mortality was definitely lower on the medium and high animal protein levels than on the low animal protein ration. It was also consistently higher on all levels of vegetable protein.

4. Cost per unit of body weight produced varied little between the 12.5% and 14.5% animal protein levels but was approximately 8% less for the 14.5% than for the 17% level of protein. In spite of lower cost of the vegetable protein supplement these groups were slightly less economical than those on animal protein. The higher mortality of the vegetable protein groups, if reduced to a cost basis, widens the gap between animal and vegetable protein rations still further if considered on a basis of economy of production of growth.

Evidence is presented to show that the pasture was utilized to an increasing degree on the lower levels of protein. The high animal protein ration (17%) would appear to have been adequate in most respects since the pasture of the group on this ration was only very lightly grazed. There is a suggestion that the vegetable protein groups felt the need of supplementing their ration to a greater degree than the animal protein fed groups through an increased intake of pasture grass.

In consideration of the results obtained as judged by all the above criteria, it is concluded that feeding a 15.5% protein mash to seven weeks followed by a systematic reduction of protein by dilution with scratch grain so that a ratio of 3 parts of grain to 1 of mash (13.7% protein) was reached at 24 weeks (average protein ingestion of 14.5%) may be expected to give as satisfactory results as the usual practice of 20% to 14.75% with a 17% average when pasture is available as was the case in this experiment. Since the paddocks used in this test were over-pastured and the growing season particularly dry, the above conclusion would hold under most conditions.

It is also concluded that a protein level of 12.5% using increasing ratios of scratch grain as above is too low for satisfactory results.

Vegetable protein when making 99% of the total protein of the ration on the average cannot be expected to give as good results as animal protein under conditions similar to those pertaining during this experiment. Results obtained were reasonably satisfactory, however, and in time of scarcity of suitable animal feeds or where price differentials are more in favour of the vegetable protein supplements than was the case in this instance, they would fill a very useful place in the poultry feeding regime even up to almost complete substitution for animal protein feeds.

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THE RICHARDSON GROUND SQUIRREL, *CITELLUS RICHARDSONII* SABINE, IN SOUTHERN ALBERTA: ITS IMPORTANCE AND CONTROL

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The greater part of the material in the following article was gathered during the course of the Alberta Rocky Mountain Spotted Fever and Sylvatic Plague Survey. This survey was organized in 1938 and has been in the field every summer since that time. As the survey deals particularly with the Richardson ground squirrel, it was necessary that much information regarding its life history, habits, etc. be gathered so that an appreciation of its role in disease transmission could be had.

HISTORICAL

Ever since the first settlers moved into southern Alberta and began to cultivate the land, the Richardson ground squirrel (or as it is mistakenly called—the Prairie Gopher) has been recognized as a serious agricultural pest from its habit of invading grain fields and vegetable gardens where it feeds on and destroys the tender shoots and seedlings. Large fields of grain and entire garden patches have been completely destroyed by this rodent.

As more settlers arrived and more land came under cultivation so did the ravages of this pest increase, until at last an organized effort for control was demanded by the farmers. This demand was heeded, and the Provincial Government by statute empowered Local Improvement Districts in 1907, and councils of Rural Municipalities in 1911, to make provision for combatting the ground squirrel nuisance through the expenditure of public monies (17).

Two methods of control were adopted:

1. The distribution of free "gopher poison".
2. The payment of a cash bounty for each animal destroyed.

The first method was a more or less haphazard affair. The poison was issued by the Municipal Secretary to those farmers who called for it at his office; but at no time was a definite control campaign organized over a large area. The results of such a haphazard method would be obvious. Those progressive farmers who had an interest in farming and were trying to become established carried out an intensive control campaign on their own land, while less-interested farmers did not attempt any control. But these less-interested farmers were not the only offenders—lands owned by Dominion and Provincial governments, the Hudson's Bay Company, and

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the railway companies were also left unpoisoned. Such lands were ideal places for the multiplication of these pests and as a consequence the number of ground squirrels increased rather than decreased.

The second method was the better of the two because the payment of a cash bounty for the destruction of ground squirrels had a great appeal to school children, especially small boys. With the bounty as an inducement the school children snared, trapped, shot and poisoned ground squirrels and removed the tails which had to be handed in as proof that the animals were destroyed.

With the establishing of fur farming in this province ground squirrels became of some economic importance. Mink and fox farmers, especially, began using ground squirrels as a food for their animals, and in certain areas these farmers paid cash for each animal delivered to their farms. The only stipulation they imposed was that the animal must have been shot or trapped. Once again small boys entered the picture and in fur farming areas the ground squirrel population rapidly decreased.

In 1937 a mink farmer at Stanmore died from some disease highly suggestive of bubonic plague, and the circumstances surrounding his death suggested that he might have contracted the infection from ground squirrels in his district.

In 1938 an investigation into the circumstances surrounding his death was undertaken, and in 1939 it was definitely determined that the ground squirrels in his area were carrying bubonic (sylvatic) plague infection; it was further determined that he, in all probability, died from bubonic plague contracted from infected ground squirrels (4, 13, 14).

In 1940 the bounty on ground squirrels was removed and warnings against the handling of these animals were issued. At the same time an appeal was made for farmers and others to carry on more intensive poison campaigns for by so doing they would not only protect their crops but also their health (5).

THE ANIMAL

The Richardson ground squirrel, *Citellus richardsonii* Sabine (2), is often mistakenly called the prairie gopher; it also goes by the common names of yellow gopher, flicker tail and picket pin gopher (17). These names are not correct, for this animal is a Spermophile and should always be referred to as a ground squirrel.

Description

This animal (Figure 1) when full grown is about 12 inches long and varies in colour from tawny to a near-white. There is a great variation in size and colour in different areas and this variation is likely due to the soil type and kind of food.

The ground squirrels in the extreme southern part of the province are usually 10 to 12 inches long and brownish-grey in colour, while those north of a line drawn east from Calgary are predominantly larger and a greyish-white in colour. There is a very definite intermingling of size and colour

in this species throughout the whole of southern Alberta; in fact, so much so that one is led to believe that there are numerous sub-species of this animal inhabiting the same range.

Life History

The life history of this rodent is fairly simple. The hibernating animals appear in early spring, March or April, depending upon the kind of weather prevailing, and as soon as they emerge mating takes place. The period of gestation is about 27 days, and the young are born covered with fur. Within a few days after birth the young can fend for themselves. Six to eight are born to a litter and there is only one litter per year. Young ground squirrels become noticeable in Alberta during May.

FIGURE 1. Richardson Ground Squirrel.

When a month or two old the young ground squirrels establish their own burrows, usually near the parent, and carry on their own life. The colony tendency, although present, is not as highly developed as that which pertains in the Columbia ground squirrel, yet it is sufficient to keep the animals grouped close together. This gregarious habit has a definite protective value for at the first sign of danger the ground squirrels dive into the nearest burrow. It is doubtful if there is a great deal of "visiting" in neighbouring burrows, for it has been observed that the occupant resents the invasion of its burrow by its neighbours except in times of danger.

During the late summer preparations are made for hibernating, and each animal busies itself in collecting grass for its nest, and a store of seeds, roots and bulbs for food. The material gathered during these foraging trips is carried to the nest in the cheek-pouches. At the first sign of cold weather, usually around September 15, the majority of the animals are in hibernation. This will, of course, vary with the kind of fall weather prevailing and on October 12, 1942, a very warm, sunny day, many Richardson ground squirrels were still active.

Habits

The Richardson ground squirrel is a prairie-inhabiting rodent and lives in the ground. The burrows, which are used as shelter, vary in depth and length depending upon the soil type and time of year. The winter burrows are usually very deep and approach 20 feet in length, while the summer burrows are shallow and 8 to 10 feet long. Each summer burrow has an average of 8 openings scattered over an area 10 to 15 feet in diameter; the winter burrow contains a grass-lined nest and a store of food, and has only one opening which is plugged from the inside by the ground squirrel when it goes into hibernation.

The usual burrow entrance consists of an opening on one side of the mound that contains the soil removed from the burrow. This mound serves both as a protection for the burrow entrance and as an observation post for the animal. There is, however, another type of entrance that is frequently noticed in the spring and summer. It is a small, round hole in the ground and is devoid of any mound. This burrow is made by the young ground squirrel and leads from the nest to the ground surface, and as it is dug from the inside of the nest, all of the soil is pushed back into the winter burrow and is likely removed by the mother ground squirrel.

It is held by some that ground squirrels hibernate close to the ground surface, and as proof of this there are records of hibernating ground squirrels being turned up during early spring ploughing. This appears reasonable for it is obvious that this animal would hibernate above the burrow level in order to escape the flooding that would occur from rain and melting snow seeping into the burrow.

Ground-squirrels are mainly vegetarians feeding on seeds and roots, with wild onion being one of their favorite foods. They are also particularly fond of such insects as crickets, grasshoppers, caterpillars and cutworms. The authors have observed them digging cutworms from the soil and eating them. Carnivorous tendencies, although latent, appear to be well developed and these rodents are often observed feeding on the carcasses of other ground squirrels, especially on highways where the animals have been run over by automobiles. In such cases the killed animals are usually flattened out with the entrails showing. The fact that the blood and entrails are exposed may act as an attractant and be responsible for the carnivorous habit, for this action has never been observed in fields and on prairie land.

Ground squirrels have definite periods of time which they spend in the open. These periods are usually devoted to feeding, and to the collecting of material to carry them through the winter. The first period of daily activity starts about daylight and lasts for approximately two hours. The next period continues from about 10.00 a.m. to 2.00 p.m.; and the final period extends from about 4.00 to 8.00 p.m. At these times the animals can be seen sitting up like "picket pins", or dashing back and forth in their search for food. At all other times of day those ground squirrels that venture forth are very wild and scurry madly from burrow to burrow (3).

Weather conditions have considerable effect on their activity. During high winds the animals do not venture far from their burrows and are on the alert for any possible danger. During rains they will venture forth in the late afternoon to feed, and at this time they appear very sluggish.

In common with other types of wild animals the ground squirrels have no mercy on their deformed or crippled members. Such members are attacked and killed or driven out of the area. Sickly animals are also destroyed and often their burrows are taken over by their destroyers.

Range

The range of the Richardson ground squirrel covers practically all of the Great Plain area in Canada, and in Alberta (Figure 2) it is native to all of that region bounded as follows:— on the east by the Saskatchewan border; on the south by the Montana border; on the west by the C.P.R. from Pincher Creek to Lacombe; and on the north by the Battle River (3, 4, 6, 7, 8, 17).

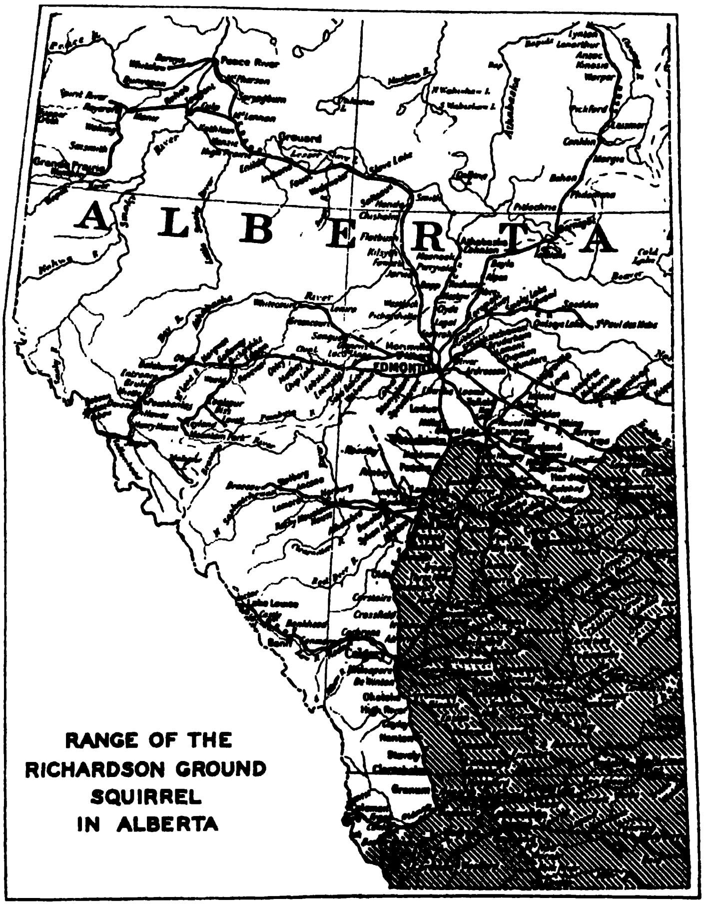

FIGURE 2. Range of the Richardson Ground Squirrel in Alberta.

Along the foothills this animal has invaded the range of the Columbia, or Mountain ground squirrel, and specimens have been taken at Cowley, and in the Red Rock Canyon at Waterton. There is a very interesting situation along the foothills where these two species meet, for a very definite intermingling of burrows occur. There is no known records of these animals cross-breeding, but the fact that the animals occupy the same limited range suggests that they are tolerant of each other (3).

Enemies

The ground squirrel has a long list of natural enemies. Of these, in order of importance, are: hawks, owls, weasels, badgers, coyotes, snakes, dogs and domestic cats.

Hawks are the greatest single factor in the natural control of ground squirrels, and every effort should be made to encourage their increase by declaring them a protected bird. As the law stands at present these birds may be shot at any time.

Owls play a very important part in control, especially burrowing owls, for they catch and eat large numbers of ground squirrels. However, the burrowing owl occupies a unique position because its value as a control agent may be offset by its ability to carry and transmit infected ground squirrel fleas (8).

Weasels, which are vicious blood thirsty killers, account for large numbers of ground squirrels each year. Their method of attack is direct and they will plunge headlong into a burrow after their victim. They usually seize their prey by the back of the neck and with one snap of their razor-like teeth they sever the spinal column. The ground squirrels have a great fear of weasels and when one invades their territory they all flee, squeaking with terror, for their burrows.

Badgers and coyotes, because of their scarcity have not, in late years, been a very important means of control.

The importance of snakes is not well understood and much confusion exists in regard to the part that they play in control. It is often stated that when rattlesnakes invade an area the ground squirrels immediately disappear, and it is commonly supposed that the snakes kill the animals. This theory does not hold up under observation for ground squirrels have been found in large numbers in areas thickly infested with rattlesnakes.

In one area of prairie land north of Medicine Hat ground squirrels have practically disappeared and although rattlesnakes are present it is obvious that they are not responsible for the disappearance (3, 8).

Dogs and domestic cats exercise only a slight control on ground squirrel numbers, and this only in thickly settled regions.

Ectoparasites

Ground squirrels, in common with all animal life, suffer from ectoparasites. These are usually lice, fleas and ticks, although there are other insects that sometimes attack these animals.

The lice are not of much importance, and as they have never been studied in detail their species are not well known.

The fleas, because of the fact that they can, and do, transmit a serious rodent infection from ground squirrel to ground squirrel, and from ground squirrel to man, are of great importance and considerable attention has been paid to them (5, 7, 12, 13, 14, 19, 20).

The following list records the fleas known to infest the Richardson ground squirrel in Alberta (7):

Name	*Locality taken*
Opiscrostis labis J. & R.*	Stanmore
Opisocrostis tuberculatus B.	Stanmore
Oropsylla rupestris Jord.*	Stanmore, Lethbridge
Hystrichopsylla dippiei Roth.	Stanmore
Epitedia spp.	Stanmore
Tamiophila spp.	Stanmore

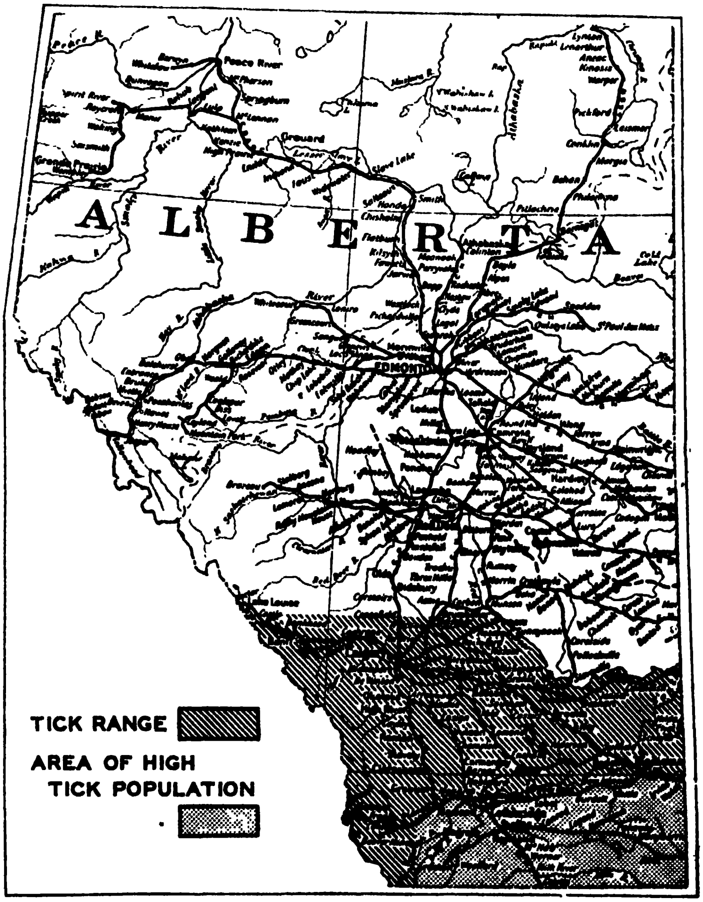

FIGURE 3. Tick Range in Alberta.

The Richardson ground squirrel is the main host for a tick that is of great importance to public health in this province (1, 3, 4, 6, 8, 10, 22). This tick, *Dermacentor andersoni* Stiles, is commonly called the "sage tick", "wood tick", "sheep tick" and "spotted fever tick". It actually is the Rocky Mountain spotted fever tick and should be known as such. The range of this tick extends from the Saskatchewan boundary to the British Columbia boundary, and from the Montana boundary to the Red Deer

* Known transmitters of sylvatic plague.

River. The area of highest population is located in southern Alberta, south of the Canadian Pacific Railway from Walsh to Macleod (Figure 3). It is this area, too, that contains the highest percentage of Rocky Mountain spotted fever and Tularaemia infected ticks (8).

Many other species of tick also infest the Richardson ground squirrel but so far only the one species has been identified.

Internal Parasites

No definite attempt has been made to collect and study the internal parasites of the Richardson ground squirrel, but observation carried on during the past 5 years show that in certain areas these animals are heavily infested with various parasites. The Hanna-Youngstown-Cessford, and the Brooks-Bassano areas contain a very high percentage of parasitized animals. These parasites infest either the alimentary tract or the liver or both.

The parasites collected consisted of tapeworms, roundworms and a small worm in the liver. Specimens sent to the Parasitologist at Parasite Institute, Macdonald College, Quebec, were identified as follows:

Filaria, new species
Capillaria hepatica—eggs in the liver.
Spirura sp. probably *infundibuliformis*.
Physaloptera sp.

"Scabby Gophers"

Ground squirrels are often seen that have large scabs on the back and sides. The cause of these scabs is not known but it is believed that they are healed wounds received during mating or in an attempt to mate. The Alberta survey has examined many "scabby" animals but the lesion does not extend below the skin. A widely held belief which may be true, states that this condition is due to mange.

Population

In order to arrive at a proper estimate of ground squirrel population it is necessary that each type of land, from virgin prairie to irrigated land, be evaluated separately and accurately as to its population (8).

Observations carried out over a 5-year period give a very accurate picture of population conditions and, paradoxically enough, those areas in which the ground squirrels *appear* to be the most numerous are the areas (with the exception of irrigated districts) in which the population is the lowest; and the reverse is also true. Such a statement is hard to believe, but when each type of land is examined separately the truth of the statement becomes apparent.

Prairie land, which is the natural habitat of ground squirrels, *appears* at first glance to harbor very few animals per acre. If, however, an acre is surveyed closely it will be found that the ground squirrels are scattered evenly over the whole area. Counts show that there are approximately 60 burrows per acre, and allowing 8 burrows per animal this gives a population of about 8 ground squirrels per acre. The point to remember is that there is an even distribution of animals over the whole acre.

Grassland which approaches prairie in regard to the fact that it is seldom, if ever, cultivated has the next highest population with approximately 6 ground squirrels per acre. Here again the dispersion over an acre is uniform and these animals are not apparent to the casual glance.

Abandoned land is land which was originally prairie, then broken and cultivated, and is now in the process of going back to native grasses. This type of land is usually badly infested with weeds and may contain numerous "blow-out" strips in which the soil lies bare. The *apparent* population on this type of land is very high for the animals are concentrated on the grassed-over land and appear very numerous. On examination, however, it is found that large areas are devoid of animals, and a count will show that the average population is about 5 ground squirrels per acre.

From the number of ground squirrels visible along the roads and on the headlands in intensively cultivated areas it would *appear* that the population was very high. If, however, such areas are examined in detail it soon becomes apparent that practically all of the ground squirrels are concentrated in such places, and that the cultivated land is entirely free of animals. In other words, there is a concentrating of ground squirrels along the margins of cultivated fields. This is a very hard fact to grasp at first but actual counts show that the average population is approximately 3 ground squirrels per acre.

Under irrigated conditions the ground squirrel population on all types of land is reduced to a minimum, for irrigation acts as a control agent through the flooding of burrows and the drowning of animals. On this type of land the average population is about 2 animals per acre.

Table 1 shows the approximate population per section for each type of land. (8).

TABLE 1.—INCIDENCE OF GROUND SQUIRRELS

Land	Animals per acre	Burrows per acre	Animals per section
Prairie	8	64	5,120
Abandoned	6	48	3,840
Grassland	5	40	3,200
Cultivated	3	24	1,920
Irrigated	2	16	1,280
Total	24	192	
Average	5	40	3,200

IMPORTANCE

Up until 1938 the Richardson ground squirrel was a very serious agricultural pest, and a large amount of public money was spent yearly in an attempt to control its ravages. Since 1938 this animal has been demonstrated as being a serious threat to human health, yet there has been a definite decrease in the amount of money spent on its control. This decrease is due to the fact that the bounty was removed in order to protect school children against a serious infection that is carried by these animals (5).

Such a state of affairs is hardly logical where more money is spent to protect crops than is spent to protect human health, and it is time that serious consideration was given to the ground squirrel situation, and long-term plans for control were laid. These plans should enlist both the Department of Agriculture and Department of Health and should include methods for organized control over all of southern Alberta.

The importance of ground squirrels can be classified under two headings: (1) agriculture and (2) health.

Agricultural Importance

The damage this animal does to field crops and gardens is well known and no further discussion is required.

Health Importance

It is only since 1938 that ground squirrels have assumed a place of importance in regard to human health, and this was brought to light by the activities of the Alberta Rocky Mountain Spotted Fever and Sylvatic Plague Survey. The importance of this animal to human health takes two forms: (1) directly, through the carrying and transmitting of Bubonic (sylvatic) plague infection; and (2) indirectly, through acting as host to spotted fever ticks, *D. andersoni*, which carry and transmit Rocky Mountain spotted fever and Tularaemia (1, 4, 10, 13, 14, 22).

The relationship of these diseases to ground squirrels will be discussed under separate headings.

Sylvatic Plague

This is the Bubonic Plague or Black Death of history, and it is primarily a disease of rodents that can be transmitted to man by the handling of infected animals or by the bite of an infected rodent flea (4, 13, 14, 18, 19, 20).

The causative organism of plague in both man and rodent is *Pasteurella pestis*.

Plague is usually fatal to rodents and often appears amongst them as an epizootic (12, 18, 19). At such times many ground squirrels die bringing about a visible decrease in their numbers. When the animals die their fleas transfer to the first available host for a blood meal and, if they happen to be infected with the plague organism, they will transmit this infection to that particular host. It is possible for these fleas to transfer to, and feed on, man.

Fleas are not the only means whereby the infection is transmitted, for a plague-sick ground squirrel may develop lung complication giving rise to a "pneumonic" type of plague. This type is highly contagious, and is spread from animal to animal, and from animal to man through droplet infection.

Plague in man takes three forms. First a "bubonic" type in which the glands next to the site of infection become enlarged and pus-filled. This type is usually contracted from the bite of an infected flea but it is very seldom fatal. Next a "septicaemic" type in which the plague organism invades the blood stream and causes complications. This type may follow the "bubonic" type or it may be caused by handling infected animals. Quite a few deaths result from this type of infection. The third or

"pneumonic" type is the most serious and is due to the invasion of the lungs by the plague organism. Practically all cases of this type result in death (20).

There is every reason to believe that one death from pneumonic plague contracted through handling infected animals has already occurred in this province (4, 5).

There are at least 2 species of ground squirrel fleas present in this province that can, and do, transmit plague infection (7).

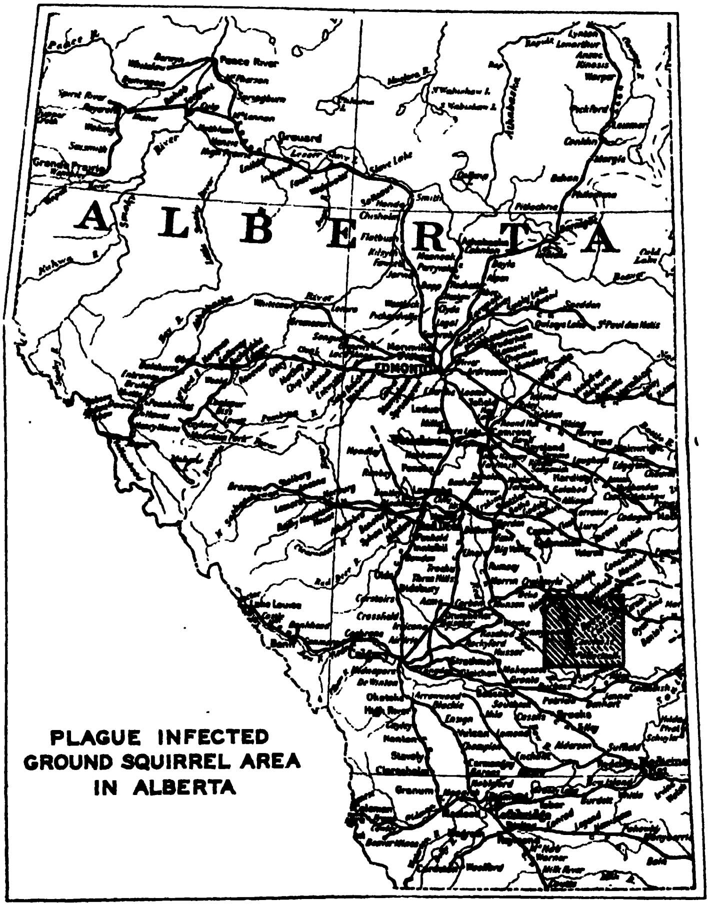

FIGURE 4. Plague Infected Ground Squirrel Area in Alberta.

Besides these there is the human, or cosmopolitan flea[3], *Pulex irritans*, that can also transmit plague under certain conditions.

Plague infected ground squirrels have been found over an area of 2,000 square miles east of Drumheller (Figure 4), and there is good evidence that other plague areas will be discovered in Alberta in the near future (8).

Rocky Mountain Spotted Fever

Rocky Mountain spotted fever is a serious disease of man that is produced by an organism known as *Dermacentroxenus rickettsi*, and is

[3] This species was taken from a badger in the Stanmore plague area in 1940.

transmitted to man through the bite of an infected spotted fever tick *Dermacentor andersoni* (1, 10, 22).

Many species of rodent act as natural reservoirs for this disease but they never suffer any ill effects from it.

The life history of the spotted fever tick is very complicated, and during its development it requires 3 different types of host animal (10, 22). The Richardson ground squirrel acts as a host animal during the second or

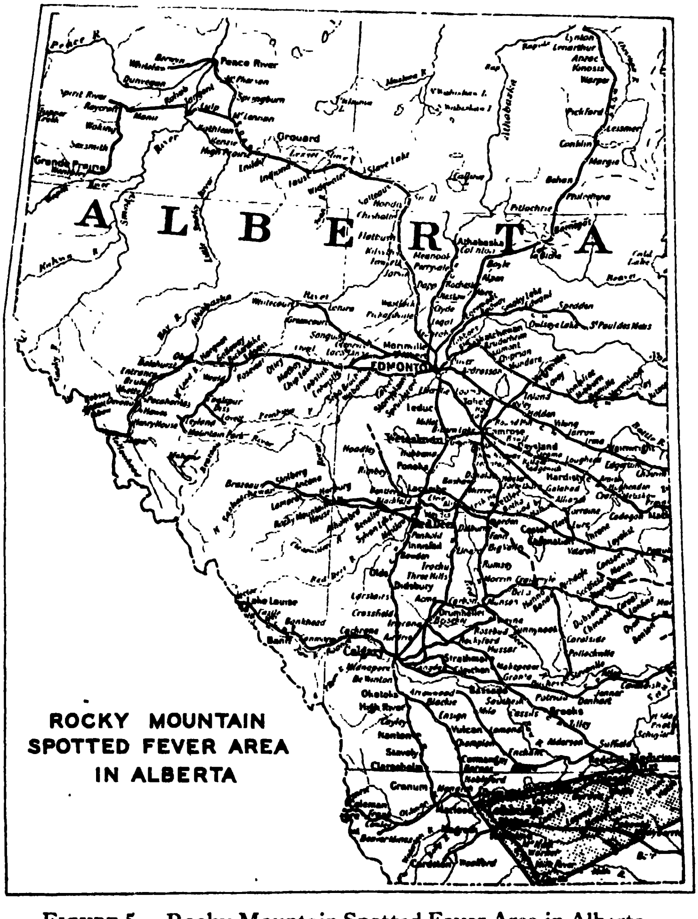

FIGURE 5. Rocky Mountain Spotted Fever Area in Alberta.

nymphal stage of its life cycle. During this stage the nymph tick feeds on the blood of the ground squirrel and if the rodent is carrying the spotted fever organism the tick picks it up, and then during the adult stage it will transmit it to the host animal on which it feeds. As adult ticks often attach to man the infection is then passed on to them, usually with serious consequences, if not death, as the result.

There is a very large area of Rocky Mountain spotted fever infection in the Milk River-Lethbridge-Medicine Hat-Manyberries district (Figure 5), and 6 human cases with 4 deaths have occurred since 1936. The last death occurred during July, 1942 (8).

Tularaemia

This disease, which is commonly called rabbit fever, can be transmitted to man through handling infected animals; by the bite of an infected tick, *D. andersoni*; and by the bite of an infected deer fly, *Chrysops discalis* (22).

The causative organism is *Pasteurella tularense*. This disease has been found in ground squirrels, and in ticks attached to, and feeding on, ground squirrels (8).

Tularaemia is assuming serious proportions in Alberta and it was been demonstrated that ground squirrels play a very important part in its spread through acting as reservoirs for the infection.

Equine Encephalomyelitis

The common name for this disease is "sleeping sickness in horses". It occurs in epidemics and it is believed that about 3 years elapse between outbreaks. The causative organism is suspected as being a virus.

The epidemiology of this infection is not well understood. Some authorities (21, 28) hold to a theory that it is transmitted by mosquitoes.

Gwatkin (16) demonstrated that there are indications of the virus in the brain of the Richardson ground squirrel. The Alberta Sylvatic Plague Survey, from work carried out during 1939, 1941, and 1942, believes that the ground squirrel plays a very important part in epidemiology of this disease.

NEED FOR CONTROL

From the foregoing information it is readily recognizable that a grave need for an effective ground squirrel control campaign now exists. Such a campaign should be organized to cover a large area and should be designed to reduce ground squirrel population to a minimum. It is obvious that such a campaign should have a central office, and it is suggested that the departments of Health and Agriculture assume joint control.

All control campaigns organized in known or suspected plague areas should come under the direct control of the Sylvatic Plague Survey with the work being carried out by the Department of Agriculture. In other areas the campaign would be directed and controlled by the Department of Agriculture.

Provision should be made in the Pest Act for fines, etc. to be levied against those land-owners who refused to co-operate in controlling the ground squirrels on their property during the operation of the campaign.

Control Methods

In various places in the United States and Canada 3 methods of control have been practised successfully. These are poisoning, trapping and fumigation. Each method has certain outstanding features and gives excellent results under ideal conditions, but poisoning is the most common and effective control.

Poisoning

Experience has shown that the use of poisoned grain is the cheapest and most effective method for killing ground squirrels.

Many commercial preparations are on the market as "gopher-poisons". These poisons, before using, are mixed with varying amounts of grain, and most of them have strychnine as the killing agent. Other poisons, such as sodium arsenite, have also been used with good results.

It should always be remembered that any substance poisonous to ground squirrels is also poisonous to other animals and human beings. Care must be taken to keep both the poison and the poisoned grain out of reach of small children and domestic animals.

Poultry and wild game birds cannot be killed with poisoned grain.

Distribution of Poisoned Bait

The best results are obtained if the poisoned bait is put out early in the spring. The time will vary according to the season, but the poison campaign should not be started until at least 90% of the ground squirrels are out of hibernation. In distributing the bait care should be taken to treat all burrows, and in order to make sure it is suggested that each burrow on being treated be marked with a piece of lath. If this method is followed then new burrows can be located as soon as they are made and be treated immediately.

A poison campaign should be well organized and faithfully pursued. Bait should be distributed at least every 2 weeks until it loses its attraction for the animals. This usually happens when the vegetation becomes green.

Poison campaigns should be organized on a large scale, either by districts or municipalities, and every person resident in the campaign area should be encouraged to do everything in his power to control the ground squirrels on his land (11). Vacant lands should be treated as thoroughly as the settled areas, and especial attention should be paid to road allowances.

The Alberta Sylvatic Plague Survey organized and carried out an effective control campaign on 72 sections of land in the Hanna-Stanmore area. This campaign was a model of efficiency, and it is doubtful if a single burrow was missed. In this campaign 15 men were employed and they poisoned approximately 1,280 acres per day (4).

In poisoning cultivated land particular attention should be paid to the headlands for it is in such places that the animals will have their burrows.

Poison Baits

The following types of poison baits have been developed by various governmental agencies and all have yielded good results. Practically all of these baits have strychnine as the killing agent, but there are certain modifications as to mixing and distributing. The following recipes for these baits are listed with comments.

Montana Baits

Spaulding (26) recommends the following types of bait as being both cheap to manufacture and easy to distribute.

1. *Starch-coated Grain*

Wheat or barley	8 quarts
Strychnine (sulphate or alkaloid, powdered)	¾ ounce
Starch	5 tablespoonfuls
Saccharine	½ teaspoonful
Water	1½ pints

Mix the starch to a thin paste free from lumps in a little of the cold water, add the rest of the water, and bring to a boil over a slow fire. Add the saccharine and powdered strychnine. Stir well and pour over the grain. Mix thoroughly until every kernel is evenly coated. Spread on papers to dry. This may be used at once or kept indefinitely in a dry place, but should be labeled as poison. It is strongly recommended that the poisoned grain be prepared some time before it is to be used, so that it may be distributed as soon as the squirrels make their appearance in the spring. Distribute it in the morning, placing about a teaspoonful near the mouth of each occupied burrow.

For the Columbia ground squirrel increase the strychnine to 1 ounce, as this species does not take grain as readily as the other and a stronger poison is needed.

2. *Water-proofed Grain*

Where the poison is to be used while snow is still on the ground, or while the ground is still wet after a rain, the following formula is recommended.

Wheat or barley	8 quarts
Strychnia sulphate	¾ ounce
Water	2 quarts

Dissolve the strychnine in boiling water, cool slightly, and pour over the grain. Allow it to stand until the moisture is all absorbed, stirring occasionally so that it is evenly taken up by the grain. Spread on papers and dry in the sun, *never by fire*, for from 12 to 24 hours. Then heat it over a slow fire for 15 or 20 minutes with about one-half pint of melted beef suet or mutton tallow, stirring constantly to prevent scorching. Allow to cool and it is ready for use as already described.

For Columbia ground squirrels increase the strychnine to 1 ounce.

Comment: This type of bait was very effective but oats were found to be more attractive to ground squirrels. Spaulding believed that the poison bait would kill chickens.

Alberta Baits

Lawton (17) recommended the following types of poison bait, and made the following statement regarding poison baits.

"Poison should always be placed at least 6 inches into the hole. Do not place or scatter it on the ground around the hole as it may result in the destruction of some of our valuable game or insectivorous birds, or domestic birds and animals."

1. Dissolve 1 ounce of strychnine or sulphate of strychnine in 1 quart of vinegar to which has been added 1 quart of hot water. Stir with a stick until all the strychnine is dissolved, boiling if necessary. Add 1 pound of sugar or 1 pint of molasses and a teaspoonful of oil of anise. Pour the hot solution over half a bushel of wheat and add enough hot water to cover all the wheat. Let the grain stand in the solution for 24 hours, and if any of the solution is then still unabsorbed, add a handful of shorts and stir the whole mixture well. Put 1 tablespoonful of the moist grain well into the entrance of each gopher hole.

2. Mix thoroughly 1 ounce strychnine alkaloid (powdered) and 1 ounce baking soda. Sift this into three-quarters pint of thin, hot starch paste, and stir to a creamy mass. The starch paste is made by dissolving 1 heaping tablespoonful of dry gloss starch in a little cold water, which is then added to three-quarters pint of boiling water. Boil and stir constantly until a clear thin paste is formed. Add one-quarter pint heavy corn syrup and 1 tablespoonful of glycerine, then stir thoroughly. Add one-eighth ounce saccharine and stir thoroughly. Pour this poison solution over 20 quarts of clean oats and mix thoroughly so that each grain is coated. Prepare the poisoned grain 20 to 48 hours before using. For mixing small quantities an ordinary galvanized wash tub is convenient. For larger quantities a tight, smooth box may be used and the mixing done with a spade.

3. To 1 pint of boiling vinegar add 1 ounce of strychnine and stir until dissolved. To this add 2 quarts of water. While boiling add 2 pounds of brown sugar and 1 tablespoonful of oil of anise. Put this mixture into a pail and add cracked grain, handful after handful, constantly stirring, until a juicy mixture is obtained. Put 1 large teaspoonful of this into each gopher hole.

Comment: Mr. Lawton was also under the impression that the poison baits were harmful to chickens. These baits were widely used in this province until superseded by the oat type bait.

Improved Baits

Strickland (27) recommended the following bait as being more effective than poisoned wheat. He points out, however, that this improved bait is more difficult to prepare than poisoned wheat.

Poisoned Oats

Mix one ounce of finely powdered Strychnine Alkaloid and 1 ounce (1 tablespoonful) of baking soda together in a dry form.

Prepare some starch paste as follows: Dissolve 1 heaping tablespoonful of dry gloss starch in a little water. When thoroughly dissolved add enough water to make three-fourths of a pint. Boil and stir constantly till a clear thin paste is formed.

While the starch paste is still hot stir in the mixture of strychnine and baking soda. Stir thoroughly till a creamy mass is formed.

Add one-fourth pint of syrup or molasses, 1 teaspoonful of saccharine, and 1 tablespoonful of glycerine and again stir thoroughly.

Pour this mixture over 20 quarts of good, clean oats, and stir until every kernel is covered with a thin coat of poisoned starch paste.

Distribute in the morning, as directed for poisoned wheat.

Brown (5) recommends a sodium arsenite and oats bait. This bait was used in the 1940 Gopher Control Campaign at Stanmore with very good results. It is a very cheap bait to manufacture.

Sodium Arsenite and Oats

Sodium arsenite	¾ gallon
Oats	1 bushel
Water	1–1½ gallons

Dilute the sodium arsenite in the water, pour the solution over the oats and mix in a mechanical mixer. Mix thoroughly and allow to soak for 12 to 24 hours before using.

The grain may be used in a damp or dry condition. If it is desired to store the poisoned grain for some period of time it should be dried by spreading over a floor before being piled.

Comment: This bait is cheap and easy to mix, and large amounts can be mixed at a time in a mechanical mixer. During the 1940 campaign over 72 sections of land were treated with this bait, and it is estimated that about a 75% kill of animals was achieved. This formula was obtained from O. S. Longman, Alberta Department of Agriculture.

Colorado Formula No. 46

Burnett (9) developed this formula to meet Colorado conditions.

Whole oats	16 quarts
Strychnine (Alkaloid powdered)	1 ounce
Saccharine	⅛ ounce
Baking soda	1 ounce
Fine salt	½ pint
Water	1 pint
Petrolatum oil	¼ pint

Flour to thicken to a creamy paste.

Dissolve strychnine in one-half pint of cold water, then add one-half pint warm water. Stir in soda and saccharine, add salt and oil, put over fire and heat until salt is dissolved, stirring constantly. Remove from fire, stir in flour, making a creamy paste. Pour the poisoned solution over the grain and thoroughly mix. When mixed the grain is ready to use.

Poisoned grain treated with this oil, remains fresh for a greater length of time than grain treated with any other formula we have tried.

Comment: This bait appears to have all the required points essential to cheapness and effectiveness. The oil keeps the bait fresh and attractive for a long period of time.

Iowa Baits

Gunderson and Decker (15) recommend the following baits for ground squirrel control.

1. *Shelled Corn Bait*

Soak shelled corn in solution made by dissolving 1 ounce of strychnine sulphate in 2 quarts of water.

Place poisoned corn where it will be readily available to the ground squirrels.

2. *United States Fish and Wildlife Service Bait*

Mix 1 tablespoonful of laundry starch in one-half teacup of cold water, stir in three-quarters pint of boiling water to make a thin, clear mucilage. Mix 1 ounce of powdered strychnine alkaloid with 1 ounce of powdered bicarbonate of soda and stir the mixture into the hot starch making a smooth creamy paste free from lumps. Stir in one-quarter pint of heavy corn syrup and 1 tablespoonful of glycerine. Apply to 16 quarts of oats and mix thoroughly to coat every kernel.

A quart of poison grain should be enough bait for 40 to 60 holes.

Scatter lightly in teaspoonful quantities around the burrow entrance.

Manitoba Baits

Criddle (11) recommends the following baits for control of ground squirrels.

Strychnine	1	ounce
Molasses	½	pound
Wheat	1	bushel

Dissolve the strychnine in sufficient warm water to soak the grain without leaving a surplus of moisture. When used at once drying is unnecessary, but the grain should be dried quickly if it is to be kept any length of time, otherwise it will become musty or sour.

Strychnine (powder)	½	ounce
Tallow	10	pounds
Salt	1	ounce

Melt the tallow by heating and add the strychnine and salt. Keep heated until all is thoroughly mixed, then pour into a convenient receptacle to cool and afterwards cut into small lumps for placing in the gopher hole. All such baits should be placed in burrows showing recent signs of being inhabited and in quantity sufficient for one meal.

Trapping

This method is effective in gardens and around buildings. A No. 1 jump or spring trap is usually recommended. The trap should be set in the burrow entrance; bait is not necessary. The trap should be attached by wire to a 3-foot post anchored in the ground. This will prevent the animal from dragging the trap into the burrow. Periodic visits should be made to the traps to prevent undue suffering on the part of the trapped animals, and also to make the traps more effective through re-setting.

Fumigation

Calcium-cyanide, carbon bisulphide and methyl bromide are all gases that have been used very successfully in ground squirrel control. Carbon monoxide has also given very good results but it is difficult to use over large areas.

Calcium-cyanide gas in the form of Cyanogas A, a commercial preparation, is the best known fumigant and it has been used for rodent control in New Zealand, Africa, United States and Canada. Russia also carried out some experimental work but the results have not been obtained. The use of this gas will be considered in detail.

Calcium Cyanide

This gas in the form of Cyanogas has been used very successfully in various places and much information is available as to methods and amounts used. In British Columbia this gas is used extensively for ground squirrel control. The control campaigns in that province are organized as a co-operative endeavour between the farmers and the Department of Agriculture. The department supplies the gas at cost and supervises the campaign. According to a letter from the British Columbia Deputy Minister of Agriculture, excellent control has been achieved.

The Cyanogas, which is in the form of a powder, can be applied to the burrow by means of a spoon or a foot-pump that was specially designed for this work. The amount of dust used varies from 1 to 2 ounces but the majority of workers favour the 2 ounce dose. Sanders (24) working in Saskatchewan recommended that 2 ounces be placed in each burrow by using a long-handled spoon. Wade (30) recommended the same method. The State College of Washington (31) recommends the using of a dusting machine. Tillyard (29) in New Zealand, and workers in South Africa (25) also recommended dusting machines. The British Columbia department of Agriculture uses Cyanogas and dusting machines extensively[4].

Cyanogas is a deadly poison and when it is introduced into the burrow a poisonous gas is liberated from the powder. This gas acts very rapidly and kills the animal, and usually its ectoparasites, in a very short time. The gas is also deadly to human beings.

In using Cyanogas care must be taken to see that all burrow openings except the one being used for the introduction of the gas, are closed, and as soon as the burrow has been treated this opening must also be sealed. The openings can be easily closed by forcing soil into them by means of the boot-heel.

Detailed information regarding the use of Cyanogas has been secured by the Alberta Sylvatic Plague Survey, and it is of the opinion that the cost of a campaign based on Cyanogas is prohibitive, except in cases where human health is threatened, or where small areas, such as gardens and dooryards, are involved.

If it is remembered that on an average there are 5 ground squirrels per acre, and each ground squirrel has an average of 8 burrows, then there will be 40 burrows per acre. If each burrow is to receive 2 ounces it will mean that 80 ounces or 5 pounds of Cyanogas will be required for each acre. As Cyanogas costs approximately 40 cents per pound the cost for the gas alone will run to over $2.00 per acre. To apply the gas efficiently a foot-pump or dusting machine is required and this will cost in the neighbourhood of $8.00. In applying the gas this survey has discovered that one man can only treat a maximum of 8 acres per day.

The use of Cyanogas does have some very decided advantages, the first one being the fact that it is 100% effective in securing a kill. Another advantage is that it kills all of the ectoparasites, those on the animal and those in the debris of the nest. This is the main reason why Cyanogas is recommended as a control agent in plague areas.

[4] Letter.

Carbon Bisulphide

This gas in inflammable and highly explosive so great care must be taken that it is not opened near a fire or where anyone is smoking. Sparks created by the shovel hitting a stone during the closing of a burrow have been known to cause a gas to ignite. As it is a highly volatile gas the container should be kept tightly corked.

The Alberta Sylvatic Plague Survey have not had any experience with this gas. Burnett (9) recommends the following method:

> To use this gas take any absorptive material, such as dry horse-manure, corn cobs, or cotton waste, pour on a large tablespoonful of crude bisulphide, throw it as far as possible down the burrow, quickly close the hole with earth and tamp it with the foot so as to prevent the escape of the gas.

Spaulding (26) recommends the following method:

> A ball of some porous material—dried horse dung or cotton waste answers very well—is saturated with the carbon bisulphide and dropped into the hole, which is immediately plugged with dirt to confine the fumes within the burrow. The best results will be obtained when it is used after a rain, while the ground is still moist, confining the fumes more closely within the burrow and preventing their escape through the porosity of the soil. Moist soil also stops the burrow better than that which is dry and hard.

Methyl Bromide

This gas is a comparatively new one on the market. It has been used very effectively in insect control and has been tried out as a ground squirrel control. This survey has considerable literature on its use but nothing as to its effectiveness as a control.

Carbon Monoxide

This gas is generated by an automobile engine and introduced into the burrow by means of a hose pipe attached to the car exhaust. According to reports the results are very good, but again the survey is not in a position to express an opinion as to its effectiveness.

SUMMARY

1. The Richardson ground squirrel is a native of southern Alberta. It is a prairie-inhabiting rodent that lives in a burrow in the ground and spends the winter in hibernation. It is a vegetarian, feeding on roots and seeds. Only 1 litter, varying from 4 to 9 young, is born a year.

2. Up until 1938 this animal was considered as an agricultural pest only, doing great damage to field crops and gardens. In 1939 it was discovered that it was also a menace to human health in two very important, but widely different ways. The first was that it, and its fleas, were carrying sylvatic (bubonic) plague infection in certain areas in Alberta; and the second was that it was acting as a host for certain stages of the Rocky Mountain spotted fever tick—the transmitter of spotted fever to humans. In 1942 it was discovered that this ground squirrel was also carrying tularaemia—a disease that can be transmitted to man.

3. Prior to 1940 a large sum of public money was spent yearly on poison, and as a bounty, to control this pest. In 1940 this survey had the bounty removed. This step was taken to protect children from the danger of infection. Since 1940 very little money has been spent for control. This is a serious mistake and immediate steps should be taken to organize a definite control with the aim of reducing ground squirrel numbers.

4. It is strongly recommended that an intensive control campaign under the direction of the departments of Health and Agriculture be organized immediately. This campaign should have as its aim the control of ground squirrels throughout southern Alberta generally, but more particularly in the known and suspected plague areas.

5. Methods of control should depend on the degree of population, and whether the area was plague infected or not.

6. Strychnine baits have been used with great success, but there are strong indications that the sodium arsenite and oats bait may be cheaper and just as effective.

ACKNOWLEDGMENTS

All members of the Survey, since its inception, have contributed to the following article by keeping accurate records on all points relating to ground squirrels, and to them many thanks are due. To Mr. Kenneth Walker, Agricultural Fieldman, Special Areas Board, we are extremely grateful for the "gopher" population survey carried out at Stanmore in the fall of 1939. Especial thanks are extended to Dr. F. O. Morrison (now Lecturer in Entomology, Macdonald College) and Dr. G. C. Walkey (now practising in Cadomin, Alberta) for their interest and assistance in establishing the ground squirrel population study while attached to the Survey.

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BOOK REVIEWS

THE PARASITE CATALOGUE OF THE IMPERIAL PARASITE SERVICE

The rapid development of scientific and practical work on parasitic and predaceous insects during recent years has created a need for a work of reference indicating the host relations of the entomophagous species and providing in a convenient form a bibliography of the subject. To meet this need the Parasite Catalogue of the Imperial Parasite Service is now being published. This Catalogue was originally compiled on cards as a basis for the work of the staff of the Parasite Service. Its publication was suggested by the delegates to the Imperial Entomological Conference of 1935 and the British Commonwealth Scientific Conference of 1936 in the belief that it would be useful to entomologists everywhere.

The first instalment of the Catalogue, now in course of publication, comprises rearing records for parasites and predators published during the years 1912 to 1935 inclusive, and is estimated to contain about 100,000 citations. The bulk of the records have been taken from the Review of Applied Entomology and papers mentioned therein. When the publication of these records has been completed, it is proposed to publish the records that have appeared since 1935 in a series of supplements, which will be extended to include records anterior to 1912 if the sale of the parts published justifies this further effort.

The Catalogue is divided into four sections which will be issued in the following order:

Section I: Parasite Host Catalogue

Part 1. Arachnida and Coleoptera
2. Dermaptera and Diptera
3. Hemiptera
4. Hymenoptera, Isopoda and Isoptera
5. Lepidoptera A – C
6. Lepidoptera D – G
7. Lepidoptera H – M
8. Lepidoptera N – P
9. Lepidoptera Q – Z
10. Orthoptera, Psocoptera and Thysanoptera.

Section II: Parasite Catalogue

To be issued in parts of convenient size.

Section III: Predator Host Catalogue

Part 1. Arachnida, Coleoptera, Collembola and Diptera
2. Hemiptera
3. Hymenoptera, Isoptera, Lepidoptera, Mollusca, Myriapoda, Neuroptera, Orthoptera and Thysanoptera

Section IV. Predator Catalogue.

To be issued in parts of convenient size.

In the Parasite Host and Predator Host Catalogues, the names of parasites are grouped under the names of their host insects, assembled in Orders. These Catalogues give the name, family, and order of the parasites or predators, the country of record and the bibliographical references. In the section dealing with each Order, the names of host insects are listed according to genera in lexicographical order. Parasites are listed under each host in the same manner. Each part is provided with an index listing all parasites or predators cited under genera in lexicographical order.

In the Parasite and Predator Catalogues host insects are grouped under the names of their parasites and predators, assembled in Orders. These Catalogues give the name, family and order of the parasites, predators and hosts, and the country of record.

In all the parts of the Catalogue, synonyms are connected by cross-references so that hosts, parasites or predators may be found under any name used to designate them in any publication cited.

Though the Catalogue is merely a bibliographical guide to the literature on parasitic and predaceous insects, and therefore reproduces some records which are probably inaccurate, yet it constitutes an indispensable basis for investigations on parasite biology or experiments in biological control. The data on host relations often facilitates the identification of reared species and revisional work of various kinds. The Catalogue also provides a good starting point for the study of the general problems of parasite biology; presenting, in a condensed and convenient form data and references scattered here and there through the immense literature of the subject and unobtainable except at the cost of much time and trouble.

For the sake of economy the Catalogue has been printed by the Multigraph method on stout bond paper. The volumes are approximately Crown 4to. Each part is bound separately in cloth-covered boards. The price of the parts is fixed at present at $2.00 (Canadian) each and will be maintained at as low a level as basic costs permit.

Part 1, listing about 1,000 species of Arachnida and Coleoptera and about 13 species of parasites (pp. ix and 151) and Part 2, listing about 600 species of Dermaptera and Diptera, are now ready.

Parts 3 and 4 will be issued early in 1944 and the remaining parts will follow at short intervals.

Orders for these volumes should be sent to:

The Imperial Parasite Service,

Imperial Institute of Entomology,

228 Dundas St., Belleville, Ontario, Canada.

A DICTIONARY OF THE FUNGI. By G. C. Ainsworth and G. R. Bisby, Imperial Mycological Institute, Kew, England, 339 pages, 138 figures; published by The Imperial Mycological Institute, Kew, Surrey, England. 1943. Price, $4.60.

Dictionaries and glossaries of various sciences have been published for years, but the book under review may lay claim to being the first mycological dictionary, and as such is a most welcome addition to the literature on fungi. It might be described as a combined terminology of mycology and an alphabetical list of fungus genera with pertinent information, but it is rather more than that, for there are many longer sections dealing with more or less general topics of interest to both mycologists and plant pathologists.

In a foreword, the Director of the Imperial Mycological Institute, Dr. S. P. Wiltshire, points out that the book was originally designed for use by university students, but that as it developed, it became more and more technical. He expresses hope that in its final form, it will prove of service to mycologists in general. He points out the difficulties especially in respect to synonymy encountered in the compilation of the material, due to the lack of unanimity among mycologists. After a careful review of the literature, the authors have tried to reflect current mycological opinion, but are careful to point out in their preface that "by tomorrow, if not today, these decisions may be representative of neither the latest views of the authorities in question, nor the opinion of the reader and the writers."

The list of generic names of fungi includes all of those in use to the end of 1939. Later names are to be given in Supplements to the Review of Applied Mycology. For each genus its systematic position is given, together with the number and distribution of its species. The genera of the bacteria and lichens are excluded. Short accounts follow of the chief families, orders, and classes of fungi, together with explanations of terms used in mycology and illustrated with good line drawings. In addition, some fifty topics, such as, Classification, Genetics of Fungi, Sex, Entomogenous Fungi, Medical Mycology, Industrial Mycology, Plant Pathogenic Fungi, History of Mycology, Biographical Notes, are dealt with. Finally, the authors have appended G. W. Martin's most useful key to the families of fungi, which was originally published in 1941.

The authors explain that special care has been taken to see that the generic and specific names adopted are in agreement with the international Rules of Botanical Nomenclature and that the writing has been done in Basic English as far as possible.

The book is of convenient size, 5 by 7½ inches, the printing leaves nothing to be desired, and as far as one can tell without critical reading, there are very few typographical errors.

The authors have obviously put a tremendous amount of work and thought in the preparation of this book and they are to be congratulated on its excellence. For either the student or the practising mycologist and plant pathologist, it is an invaluable tool and should be within easy reach of all workers in these fields.

F. L. D.

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THE UTILIZATION OF SUNFLOWER SEED OIL MEAL, WHEAT DISTILLERS' DRIED GRAINS AND RAPESEED OIL MEAL IN POULTRY RATIONS[1]

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A survey of the literature revealed little information concerning the possible use of sunflower seed oil meal, wheat distillers' dried grains, or rapeseed oil meal in poultry rations. However, Tabakoff (3) obtained satisfactory results when as much as 20% of sunflower seed oil meal was included in a ration fed to laying hens, while Fangauf and Haensel (1) reported success when 10% of rapeseed oil meal was fed to layers. Wheat distillers' dried grains has been used extensively in the feeding of several classes of livestock, especially dairy cattle, but has not been generally accepted as a poultry feed.

I. SUNFLOWER SEED OIL MEAL, WHEAT DISTILLERS' DRIED GRAINS, AND RAPESEED OIL MEAL IN STARTING RATIONS

These experiments were set up in an attempt to replace part or all of the meat meal in a good chick starting ration with sunflower seed oil meal, wheat distillers' dried grains and rapeseed oil meal. To check each of these products 8 groups of 34 day-old Barred Plymouth Rock chicks, of which 17 were males and 17 females, were used. All birds were wing banded and weighed at the commencement of the experiment and were subsequently weighed at weekly intervals for the 10-week period which constituted the growth trials.

Three separate hatches, at 3-day intervals, supplied the chicks for these trials. The chicks from the first hatch were used for the work on sunflower seed oil meal, those from the second for the work on wheat distillers' dried grains, and those from the third were used for the experiment on rapeseed oil meal. Birds which died during the first week of an experiment were replaced by "spares" from the same hatch. Mortality during the first week was not considered to be a result of the ration fed.

All groups were started in the same type of electrically heated battery brooders in an air conditioned building, the temperature of which was thermostatically maintained at approximately 80° F. At 5 weeks of age, all birds were moved to growing batteries where they were confined for the remaining 5 weeks.

The individual ration ingredients were analysed for protein and these data subsequently used in making up rations which contained approximately 18% protein. All three products under test were considered as vegetable protein concentrates and were included in the rations to replace

[1] A contribution from the Departments of Poultry Husbandry and Animal Nutrition. J. Walker and E. C. Roberts assisted with the project and a part of the work formed their undergraduate thesis in fulfilment of the requirements for the Degree of Bachelor of the Science of Agriculture (1943). This thesis was awarded the Canadian Feed Manufacturers' prize for the best thesis in Animal Nutrition in 1943.

successively larger amounts of meat meal on a protein equivalent (N × 6.25) basis. Since the supplements in question were all lower in protein content than the meat meal, it was necessary to use quantities of the supplements which were larger than the amounts of meat meal replaced in order that the protein content of the rations might be kept constant. At the same time, the amounts of ground barley were decreased accordingly.

The same basal mixture was used in testing each of the three supplements. This basal mixture which was used for each 100 pounds of ration is presented in Table 1.

TABLE 1.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground oat groats	18.0
Ground yellow corn	18.0
Ground wheat	18.0
Cereal grass	1.0
Dehydrated alfalfa	2.5
Buttermilk powder	10.0
Salt*	1.0
Steamed bone meal	1.0
Oyster shell	1.0
Grit (insoluble)	1.0
Cod liver oil†	0.25
Total	71.75

* Contained 0.02% KI and 2.0% $MnSO_4.4H_2O$.
† Contained 400 A.O.A.C. chick units of vitamin D and 3000 I.U. of vitamin A per gram.

Although 1 lb. each of bone meal, oyster shell and grit was supplied in the basal mixture, an additional *ad libitum* supply of each was given to all groups. Feed and fresh water were before the birds at all times. Records were kept of the total group consumption of feed, oyster shell, bone meal and grit.

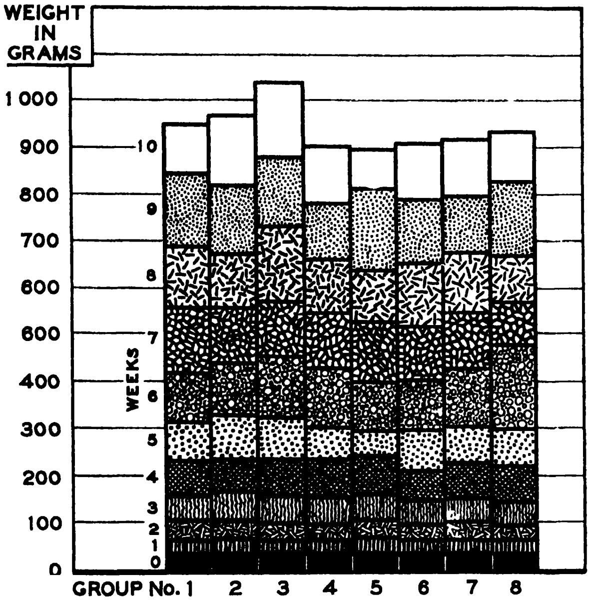
(a) Sunflower Seed Oil Meal in Starting Rations

Table 2 shows the ration composition, mortality data and average live weight at 10 weeks of age for each group. The average weekly weights and gains are presented in Figure 1.

TABLE 2.—SUNFLOWER SEED OIL MEAL IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	17.25	16.75	16.25	15.75	15.25	14.75	14.2
Sunflower seed oil meal (%)	—	2.0	4.0	6.0	8.0	10.0	12.0	14.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	1	2	3	4	2	4	1	3
Weight at 10 Weeks (gm.)	949.2	966.7	1039.4	902.4	895.2	910.3	918.2	933.4

The 10-week old weight data were analysed for significance by the method of "weighted squares of means." This method, proposed by Yates (5) has been adapted for the interpretation of data from chick nutrition experiments by Titus and Hammond (4). Tests of significance



AVERAGE WEEKLY WTS. AND GAINS

FIGURE 1. Average weekly weights and gains on sunflower seed oil meal in starting rations.

were made by means of the F test (Snedecor (2)). The F value for diet did not reach the 5% level, and it may be concluded, therefore, that the average weights at 10 weeks on the 8 diets were not significantly different.

The results indicate that under the conditions of this experiment, sunflower seed oil meal may be used to replace its protein equivalent of meat meal in amounts up to 14% of the ration, representing a complete substitution of the meat meal.

(b) Wheat Distillers' Dried Grains in Starting Rations

The wheat distillers' dried grains used in this experiment contained all of the outer coats of the wheat but did not contain the solubles. The procedure for the test with this feedstuff was the same as that for the sunflower seed oil meal. Since the protein content of wheat distillers' dried grains, however, is considerably lower than that of sunflower seed oil meal, the amounts of wheat distillers' dried grains required to replace meat meal on a protein equivalent basis were necessarily greater and the reductions in the amounts of barley correspondingly large.

Table 3 indicates the composition of the rations used in the wheat distillers' dried grains test, together with the total mortality and the average live weight at 10 weeks for each group.

TABLE 3.—WHEAT DISTILLERS' DRIED GRAINS IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	70.5
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	16.25	13.75	10.25	5.75	2.25	0.75	—
Wheatdistillers'driedgrains(%)	—	3.0	7.0	12.0	18.0	23.0	26.0	29.5
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	3	4	4	1	4	0	2	1
Weight at 10 weeks (gm.)	1001.0	871.8	874.6	969.4	921.6	861.2	880.5	879.7

It will be noted that the ration of group 1 in this experiment was identical with that of group 1 in the sunflower seed oil meal trial. However, as pointed out previously, the chicks for this experiment were from a different hatch, thus necessitating this apparent duplication. The average weekly weights and gains are shown in Figure 2.

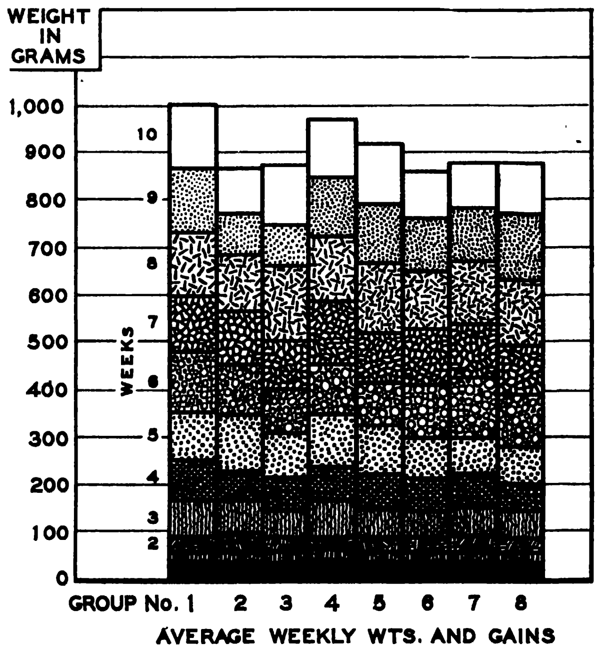


FIGURE 2. Average weekly weights and gains on wheat distillers' dried grain in starting rations.

As in the previous experiment an analysis was made on the 10-week weight data, but, in this case, the *F* value for diet exceeded the 5% point and it may be concluded that the weights were significantly different.

By application of the t test to the differences between the unweighted mean live weights of males and females on any two different diets, it was found that all groups except number 4 were significantly poorer than group 1 (the negative control group). There was no significant difference between groups 1 and 4. Since all groups excepting number 4 proved to be significantly poorer than the control, it would appear that wheat distillers' dried grains is not a complete substitute for any of the meat meal in this ration.

However, even in amounts up to 29.5% of the ration, wheat distillers' dried grains caused no mortality and the birds showed no untoward symptoms other than decreased growth. Therefore, if wheat distillers' dried grains is low in price as compared to other protein supplements or if no other more suitable vegetable protein concentrate is available, it can be used to replace at least part of the meat meal in such a ration as here employed without risk of harmful effects other than slightly decreased growth.

Other apparent disadvantages of wheat distillers' dried grains as a protein supplement for chick starting rations are its extreme bulkiness and its relatively low protein content.

(c) Rapeseed Oil Meal in Starting Rations

The procedure of this experiment was the same as that employed in parts (a) and (b). The composition of the rations, total mortality and average live weight at 10 weeks for each group are shown in Table 4. The basal mixture was the same as that used in the previous experiments. The average weekly weights and gains are shown in Figure 3.

TABLE 4.—RAPESEED OIL MEAL IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	17.25	15.75	14.25	12.75	11.25	9.75	8.25
Rapeseed oil meal (%)	—	2.0	5.0	8.0	11.0	14.0	17.0	20.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	0	1	1	1	1	3	2	8
Weight at 10 weeks (gm.)	957.9	932.5	897.2	924.4	926.2	954.2	898.5	792.9

The 10-week weight data were analysed as in parts (a) and (b).

The F value for diet exceeded the 5% level, therefore, the t test for the significance of difference between the unweighted mean live weights of males and females on any two different diets was applied. The results are shown in Table 5.

As indicated in Table 5, none of the groups fed rapeseed oil meal gave significantly better growth to 10 weeks than the control group.

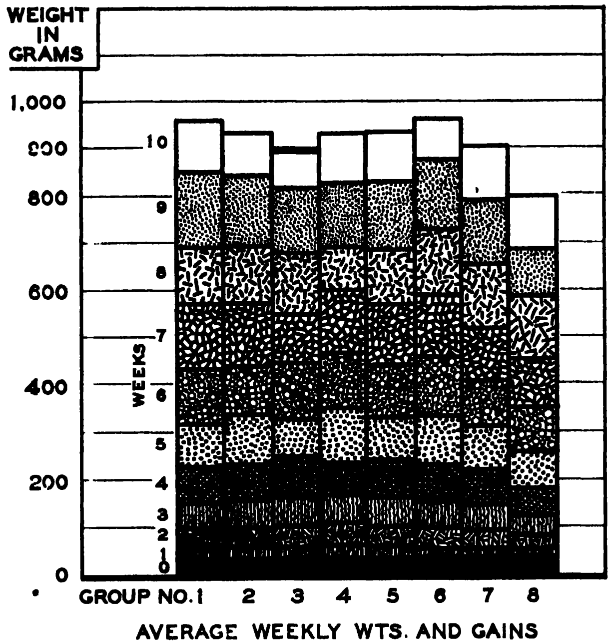


FIGURE 3. Average weekly weights and gains on rapeseed oil meal in starting rations.

As shown in Figure 3, groups 3, 4 and 5 grew quite satisfactorily up until the end of the fourth week. However, subsequent to this time, a "sour crop" condition developed in these groups, after which poorer gains

TABLE 5.—SIGNIFICANCE OF DIFFERENCE BETWEEN DIETS

Group No.	Significantly better than	Significantly poorer than
1	3, 4, 5, 7, 8	None
2	3, 7, 8	None
3	8	1, 2, 4, 5, 6
4	3, 7, 8	1
5	3, 7, 8	1
6	3, 7, 8	None
7	8	1, 2, 4, 5, 6
8	None	All

were registered. Since groups 6, 7 and 8 were fed rations containing rapeseed oil meal in higher concentrations than groups 3, 4 and 5, and since these birds did not develop the "sour crop" condition noted in the former groups, it may be assumed that the rapeseed oil meal was not responsible for the condition. Had this crop condition not arisen, it seems probable that the three groups thus affected would have given 10-week weights significantly equal to those of groups 1, 2 and 6.

When 17% of rapeseed oil meal was included in the ration (group 7), the growth during the early weeks of the experiment was somewhat reduced, and this reduction was even more noticeable when 20% rapeseed oil meal was used. However, the growth in both these groups was just as good as any of the others after the fifth week of age. This may indicate that when the birds have adapted their digestive systems to the handling of these larger amounts of rapeseed oil meal, they will make satisfactory gains.

When all the meat meal was replaced by rapeseed oil meal (group 8), there was a high mortality (Table 4). In addition, the surviving birds feathered slowly and unevenly and the feathers appeared dull and indistinctly barred.

It may be concluded, therefore, that, under the conditions of this experiment, rapeseed oil meal is a satisfactory substitute for meat meal in amounts up to 14% of the ration. When 17% of rapeseed oil meal is included, the growth during the early period of the bird's life is somewhat reduced and when 20% rapeseed oil meal is used to replace all of the meat meal, not only is there a reduction in growth during the early period of life but considerable mortality results.

II. SUNFLOWER SEED OIL MEAL AND WHEAT DISTILLERS' DRIED GRAINS IN LAYING AND BREEDING RATIONS

The experiment was planned to test the value of sunflower seed oil meal and wheat distillers' dried grains as protein supplements in a layer-breeder mash. Nine groups of 25 Barred Plymouth Rock pullets and 2 cockerels were used. The pullets and cockerels were all of the same age and breeding and were selected only for strong healthy appearance without standard disqualifications. In September, when the birds were beginning to lay, they were placed in pens which were 12 feet square and equipped with trap nests. Birds which died were replaced immediately by others of the same breeding and during the hatching season eggs laid by the replacements were not set until the birds had been in the pens for 10 days. The birds were started on the experimental rations during the last week of November, and production records were kept for a 6-month period, December 1 to May 31.

All eggs laid from February 1 to April 30, other than those which were cracked, were incubated. During the incubation season, the cockerels were rotated once a week in order to eliminate any chance of the males influencing the hatching results. The eggs were held for 3-day intervals and were set on the morning of the fourth day. The eggs were all incubated in the same 6,000-egg electric incubator and on the eighteenth day were transferred to an electric hatcher. During incubation, the eggs were candled three times—on the seventh day to remove the infertile eggs and early dead germs, and on the twelfth and eighteenth days to take out the later dead germs. All the eggs taken out were opened to check the accuracy of the candling and all the dead germs were classified according to the day they died. Notes were made on any abnormalities or malpositions. All unhatched eggs left on the trays after the completion of the hatch were also opened and classified.

The sunflower seed oil meal and wheat distillers' dried grains were considered as vegetable protein concentrates, and were included in the rations so as to replace part or all of the soybean oil meal and part of the meat and fish meals, on a protein equivalent (N $\times$ 6.25) basis. The mash was adjusted to a 19% protein level and, in order to keep the protein content of the rations constant, it was necessary, in addition to replacing the protein concentrates, to decrease the amount of ground barley in the mash as larger amounts of the supplements were included. Group 1 was used as a control.

The same basal mixture was employed in testing both supplements. This basal mixture which was used for each 100 pounds of mash is presented in Table 6.

TABLE 6.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground yellow corn	19.0
Ground wheat	5.0
Wheat bran	8.0
Wheat shorts	5.0
Ground whole oats	9.0
Rolled whole oats	9.0
Dehydrated alfalfa	4.0
Cereal grass	2.0
Dried buttermilk	5.0
Dried whey	2.5
Oyster shell	2.0
Salt*	1.0
Cod liver oil†	0.5
Total	72.0

* Contained 0.02% KI and 2.0% $MnSO_4.4H_2O$.
† Contained 400 A.O.A.C. chick units of vitamin D and 3000 I.U. of vitamin A per gram.

Besides receiving 2% of fine oyster shell in the mash, coarse oyster shell was fed *ad libitum* in a separate hopper as were also bone meal and grit. Mash was before the birds at all times and grain was fed every day before the birds went to roost on a per diem basis of 3.5 lb. per group. The grain mixture consisted of 1 part oats, 1 part corn, and 2 parts wheat.

(a) Sunflower Seed Oil Meal in Laying and Breeding Rations

The composition of the rations is shown in Table 7.

TABLE 7.—COMPOSITION OF RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
	%	%	%	%	%	%
Basal	72.0	72.0	72.0	72.0	72.0	72.0
Ground barley	12.0	12.0	12.0	11.5	11.25	11.5
Soybean oil meal	6.0	3.0	—	6.0	6.0	—
Sunflower seed oil meal	—	3.0	6.0	3.0	3.25	9.0
Meat meal	5.0	5.0	5.0	2.5	5.0	2.5
Fish meal	5.0	5.0	5.0	5.0	2.5	5.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00

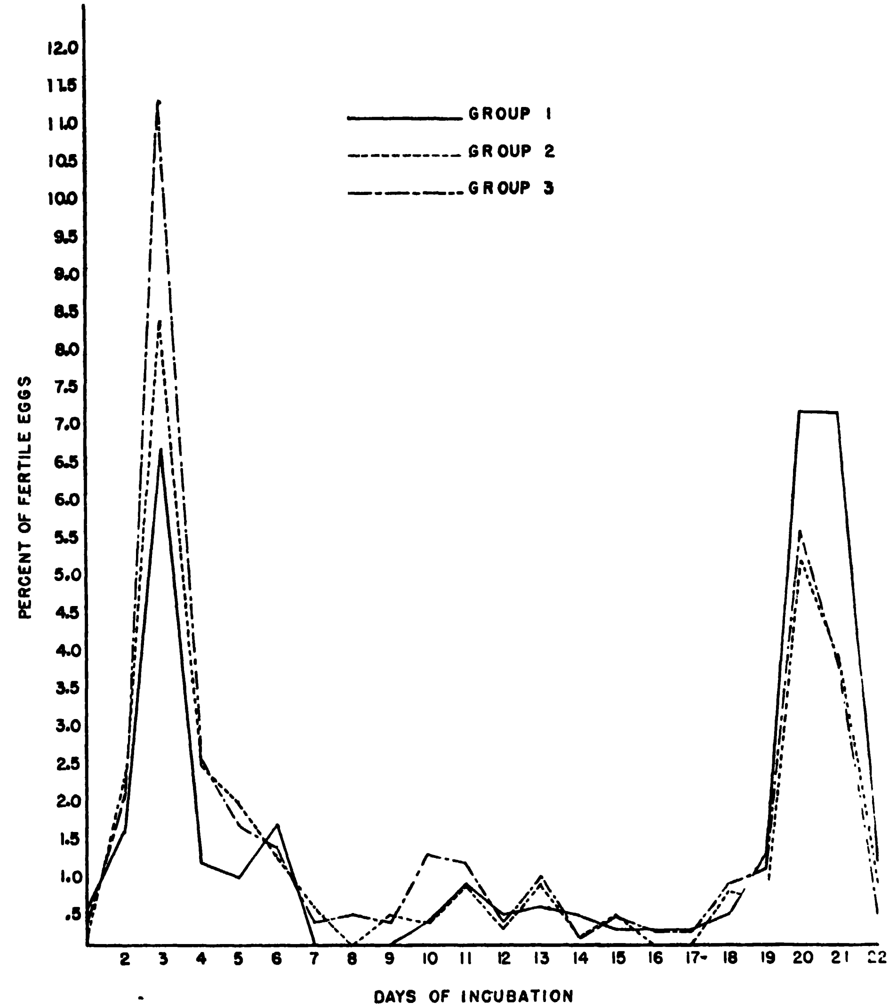


FIGURE 4. Distribution of embryonic mortality on sunflower seed oil meal in laying and breeding rations.

Figures 4 and 5 show the distribution of the embryonic mortality. Table 8 shows the egg production results for the 6-month period, and the hatchability results for the 3 months, February, March and April.

As shown in Table 8, all groups except number 4 showed approximately equivalent production. The production in group 4 was considerably lower than in any of the other groups. A study of the individual hen records revealed, however, that the group contained an unusually high proportion of birds with very low production records. Whereas none of the other groups contained more than 2 or 3 birds with a production below 25%, a level generally interpreted as indicating abnormality, group 4 contained 7 birds with productions ranging from 5 to 25%. The production of the remainder of the birds in the group was equally as good as that for any of the other groups. Hence it seems justifiable to assume that the low-production figure (42%) for group 4 is not attributable to the ration.

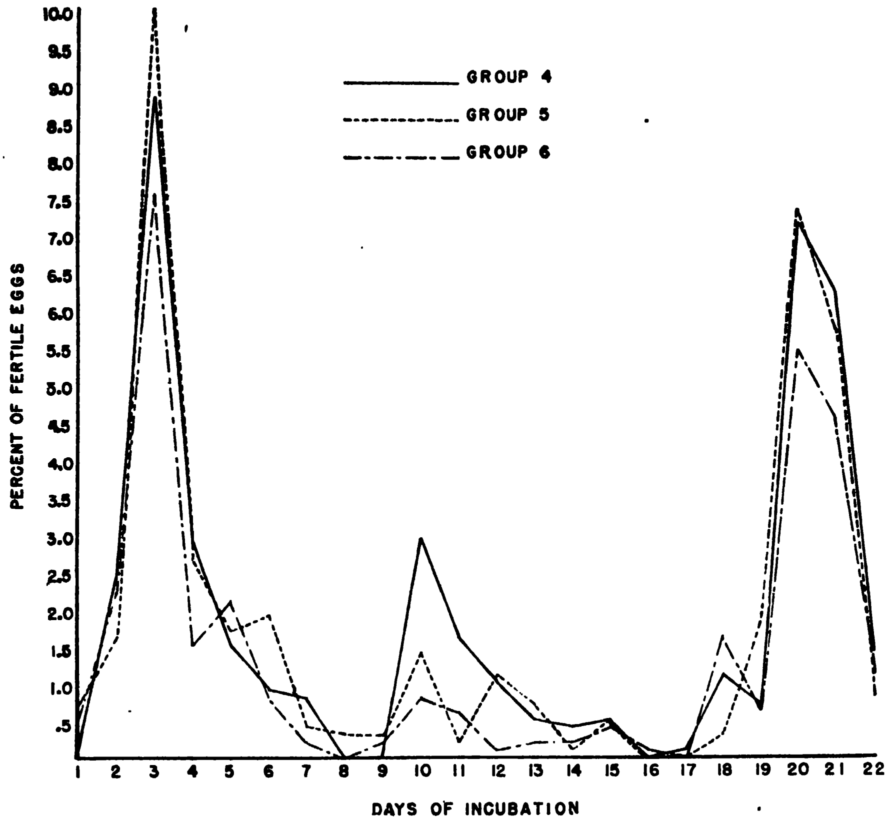


FIGURE 5. Distribution of embryonic mortality in sunflower seed oil meal in laying and breeding rations.

As shown in Table 8, there were some monthly variations in hatchability but the averages for the 3-month period did not differ markedly. All chicks appeared to be of good quality at hatching time regardless of the group from which they were hatched.

TABLE 8.—EFFECT OF SUNFLOWER SEED OIL MEAL ON EGG PRODUCTION AND HATCHABILITY

Group	Egg production Dec. 1/42 to May 31/43		Fertile Eggs set	Hatchability* Feb. 1/43 to Apr. 30, 1943			
				February	March	April	Average
	Total	%	Total	%	%	%	%
1	2456	54	1026	63.0	69.0	73.0	68.0
2	2691	59	1116	73.0	69.0	66.0	68.0
3	2421	53	1020	60.0	69.0	65.0	64.0
4	1937	42	874	57.0	59.0	63.0	59.0
5	2545	56	974	57.0	63.0	57.0	60.0
6	2510	55	814	68.0	71.0	66.0	69.0

* Based on fertile eggs set.

As shown in Figures 4 and 5, all groups had a high embryonic mortality on the third, twentieth and twenty-first days. A higher percentage of the third day mortality occurred during the winter months of February and March than in April. The mortality during the rest of the incubation period was comparatively low, except in the case of group 4 which shows an embryonic peak on the tenth and eleventh days. This peak is considerably smaller than the first and third week peaks, and the mortality here is to a large extent the result of a greater number of abnormal embryos occurring at this time. The abnormalities were for the most part comprised of oedematous and chondrodystrophic embryos. Approximately 50% of the embryos that died on or after the eighteenth day were found to be in malposition within the shell.

The results indicate that under the conditions of this experiment, sunflower seed oil meal may be used satisfactorily in the mash of laying and breeding birds to replace any one of the following: all or part of the soybean oil meal, half the meat meal, half the fish meal or finally, all the soybean oil meal plus half the meat meal.

(b) *Wheat Distillers' Dried Grains in Laying and Breeding Rations*

The composition of the rations is shown in Table 9.

TABLE 9.—COMPOSITION OF THE RATIONS

Ingredient	Group 1	Group 7	Group 8	Group 9
	%	%	%	%
Basal	72.0	72.0	72.0	72.0
Ground barley	12.0	9.5	5.5	—
Soybean oil meal	6.0	3.0	—	—
Wheat distillers' dried grains	—	5.5	12.5	20.0
Meat meal	5.0	5.0	5.0	4.0
Fish meal	5.0	5.0	5.0	4.0
Totals	100.00	100.00	100.00	100.00

Figure 6 shows the distribution of the embryonic mortality. Table 10 shows the egg production results for the 6-month experimental period and the hatchability results for the 3 months, February, March and April.

TABLE 10.—EFFECT OF WHEAT DISTILLERS' DRIED GRAINS ON EGG PRODUCTION AND HATCHABILITY

Group	Egg production Dec. 1/43 to May 31/43		Fertile eggs set	Hatchability* Feb. 1/43 to Apr. 30/43			
				February	March	April	Average
	Total	%	Total	%	%	%	%
1	2456	54	1026	63.0	69.0	73.0	68.0
7	2608	57	863	70.0	66.0	68.0	67.0
8	2441	53	914	74.0	71.0	64.0	69.0
9	2438	53	1151	71.0	70.0	69.0	70.0

* Based on fertile eggs set.

As shown in Table 10, there were only small differences in egg production between the groups receiving wheat distillers' dried grains and the control group 1. The hatchability results for the 3 months showed little variation, the difference in the average hatch between the highest and the lowest being only 3%. As in the case of sunflower seed oil meal, there was no apparent difference in the quality of the chicks at hatching time.

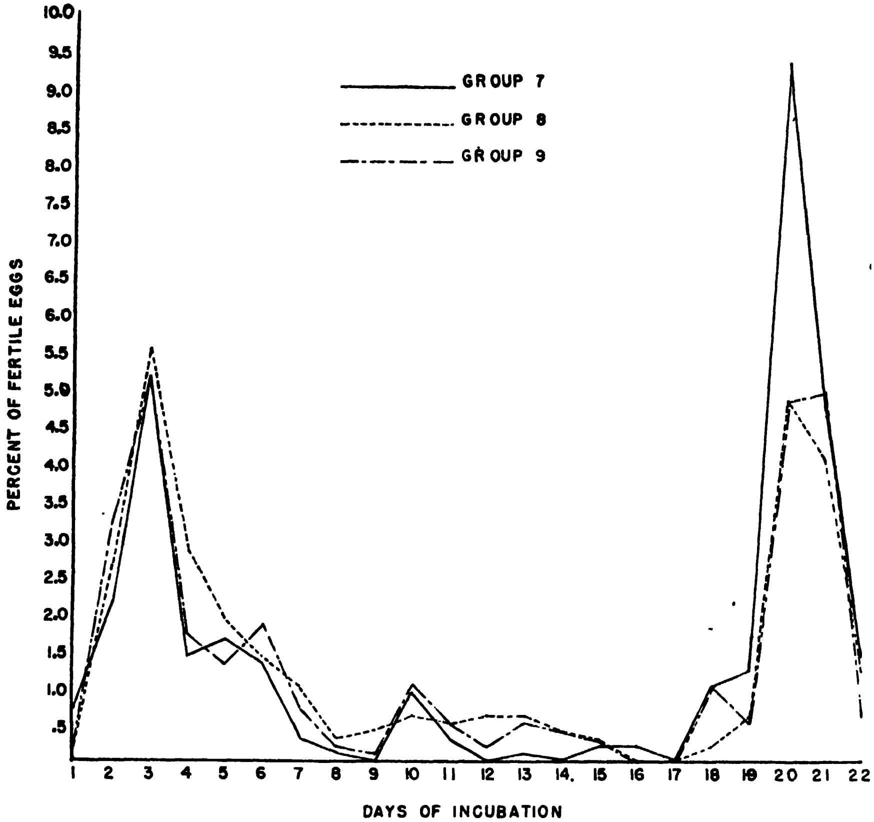


FIGURE 6. Distribution of embryonic mortality on wheat distillers' dried grains in laying and breeding rations.

As indicated in Figure 6, all groups had a high embryonic peak on the third, twentieth and twenty-first days, with comparatively little mortality at any other period of incubation. In comparison with the control group, the third-day peak for the groups receiving wheat distillers' dried grains was low, this being due to a lower mortality during the month of February. Group 7 had the highest embryonic peak during the third week because of a higher percentage of fully formed embryos which died previous to pipping the shell. Approximately 50% of the embryos which died on or after the eighteenth day were found to be in malposition within the shell.

The results indicate that under the conditions of this experiment, wheat distillers' dried grains may be used in the mash of laying and breeding birds to replace part or all of the soybean oil meal, or all of the soybean oil meal plus part of the meat and fish meals on a protein equivalent basis.

SUMMARY

An attempt has been made to substitute sunflower seed oil meal, wheat distillers' dried grains and rapeseed oil meal for meat meal in a ration fed to growing chicks. In addition, sunflower seed oil meal and wheat distillers' dried grains have been used to replace soybean oil meal, meat meal and fish meal in a layer-breeder mash.

From the results of these trials, it is apparent that sunflower seed oil meal can be used safely and satisfactorily to replace all of the meat meal in the chick starter ration here employed.

The egg production and hatchability results indicate that sunflower seed oil meal can adequately replace part or all of the soybean oil meal, or half of the meat meal, or half of the fish meal in the laying and breeding ration. It was found also that all of the soybean oil meal plus half of the meat meal could be replaced by sunflower seed oil meal in this ration without any serious decrease in egg production or hatchability.

Wheat distillers' dried grains, while not as suitable a protein concentrate as sunflower seed oil meal, produced no outstanding ill effects when included in the starter ration in amounts up to 29.5%. However, since growth appears to be somewhat retarded with the substitution of wheat distillers' dried grains for meat meal, it is recommended that this product be used in starting rations only if more suitable vegetable protein concentrates are not available, or if the cost is relatively lower than other protein feeds.

In the case of the layer-breeder mash, however, quite satisfactory results were obtained when wheat distillers' dried grains was used to replace all or part of the soybean oil meal, or all the soybean oil meal plus part of the fish and part of the meat meal. In this latter case, 20% of wheat distillers' dried grains was included in the mash.

Under the conditions of this experiment, rapeseed oil meal proved to be a satisfactory substitute for meat meal in amounts up to 14% of the chick starter used. When 20% of rapeseed oil meal was included in the ration to replace all the meat meal, however, considerable mortality and a reduction in the rate of growth during the early period of the birds' life resulted.

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AN ATTEMPT TO TRANSFER SOLID STEM FROM *TRITICUM DURUM* TO *T. VULGARE* BY HYBRIDIZATION[1]

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Solid-stemmed wheat varieties are more resistant to attacks of the western wheat-stem sawfly (*Cephus cinctus*) than are hollow-stemmed varieties, Kemp (6) and Farstad (3). Platt and Farstad (unpublished data) have found that among the solid-stemmed varieties, Golden Ball, a variety of *Triticum durum*, has been more resistant than the solid-stemmed varieties of *T. vulgare*, imported from New Zealand by Kemp (6) to this Station. Furthermore, Golden Ball has the ability to maintain its stem solidness and, consequently, its sawfly resistance under a wider range of environmental conditions than have the solid-stemmed varieties of *T. vulgare* Platt (10). It seemed desirable, therefore, to attempt to transfer the solid-stem character of Golden Ball to hollow-stemmed varieties of *T. vulgare* by hybridization. This paper summarizes the results that have been obtained.

That such a project was likely to be difficult, if not impossible, is evident from a survey of the literature. The situation appears to be this. According to Yamashita (13) there is a gene for hollowness in the C genom that is epistatic to the genes for solidness in the A and B genoms. He has labelled this gene O_D. Assuming the ordinary mechanism of meiosis in pentaploids in which the chromosomes of the C genom do not mate with those of the A or B genoms, it would seem impossible to replace O_D with a gene for solidness by hybridization. The only possibility of accomplishing such a task would be through segmental interchange between semi-homologous chromosomes from different genoms. There is considerable evidence that such rearrangements do occur, according to Huskins (5) and Love (7). The chances of obtaining desirable recombinations by such a mechanism are, of course, very small.

As this project was begun in 1937, the year Yamashita's paper was published, and as his paper was not available until some time later, it was deemed advisable to carry the project in a modified form to its conclusion. The results might be expected to substantiate or modify his interesting hypothesis.

The literature on the inheritance of solid stem and a good discussion on the possibilities of transferring it from durum to vulgare wheats has been given by Putnam (12).

MATERIALS AND METHODS

The two crosses studied were R.L. 1097 (*T. vulgare*) × Golden Ball (*T. durum*) and Regent (*T. vulgare*) × Golden Ball. Regent and R.L. 1097 were produced by the Dominion Rust Research Laboratory from the cross

[1] Contribution No. 129 from the Cereal Division, Dominion Experimental Station, Swift Current, Experimental Farms Service, Dominion Department of Agriculture.
[2] Cerealist and Graduate Assistant respectively.

H-44 × Reward. Golden Ball was imported into America from South Africa. The contrasting parental characteristics studied in this investigation are listed in Table 1.

TABLE 1.—CHARACTERS OF PARENTAL VARIETIES STUDIED

Character studied	Variety		
	Golden Ball	R.L. 1097	Regent
Stem solidness	Solid	Hollow	Hollow
Spike density	Dense	Lax	Lax
Seed length	Long	Short	—
Seed colour	Amber	Red	—
Brush length (seed)	Short	Long	—
Stem rust reaction	Mod. suscep.	Resistant	—
Leaf rust reaction	Resistant	Resistant	—
Bunt reaction	Highly resistant	Mod. suscep.	—
Chromosome no.	$n = 14$	$n = 21$	$n = 21$

The first cross was made in the greenhouse of the Cereal Division, Central Experimental Farm, Ottawa, during the winter of 1937–38, the second at Swift Current in the spring of 1939. The F_1 and F_2 were space planted in the field at Swift Current and later generations were grown in progeny rows, each line being sown in a 10-foot row on dry land and in a 5-foot row on irrigated land.

The F_2 plants of the cross R.L. 1097 × Golden Ball were classified for stem solidness, spike density, seed length, seed colour and brush length. Stem solidness was noted by splitting a main culm from end to end and recording it as solid, semi-solid or hollow. Spike density was recorded as the number of millimetres occupied by 5 rachis internodes near the middle of the spike. The other characters were classified by inspection into either of the parental classes.

Except for selected lines, only general observations were made on the F_3 and later generations.

Stem and leaf rust readings were made on certain F_7 lines by Dr. R. F. Peterson at the Dominion Rust Research Laboratory, Winnipeg. The bunt reaction of certain F_4 and F_7 lines was determined by inoculating seed with a composite collection of chlamydospores and noting the percentage of plants infected in the case of the F_4 material and the percentage of spikes infected in the case of the F_7 material. In the former, approximately 35 plants of each lines were examined and in the latter, 400 spikes of each line.

In determining chromosome numbers, the young spikes were fixed in 3 : 1 absolute alcohol and glacial acetic acid for 24 hours. They were then put through the following series of alcohols, changing at 24-hour intervals: absolute, absolute, 95%, 95%, 80%, and 70%. The material was stored in 70% alcohol. The microsporocytes were stained with iron-acetocarmine and examined at diakinesis, metaphase and early anaphase of the first reduction division. From 1 to 5 plants were examined in each of the 46 F_7 lines studied.

Selection was carried out in F_2 for plants, and in F_3 and later generations for lines, having various of the vulgare characters listed in Table 1 combined with stem-solidness. The vulgare characters were used as convenient indicators of vulgare genotype although characters such as brush length have no value in themselves.

RESULTS

No attempt was made to study the mode of inheritance of the characters examined. However, the numbers of plants occurring in the various phenotypes in the F_2 are presented in Table 2. It was noted that plants classified as solid-stemmed in the F_2 were, with a few exceptions, solid in the F_3. These exceptions will be referred to later and were from plants having an unusual combination of characters. Those F_2 plants with amber seeds also produced F_3 lines having this characteristic. All other phenotypes segregated in the F_3.

TABLE 2.—THE BREEDING BEHAVIOUR OF R.L. 1097 × GOLDEN BALL FOR SEVERAL CHARACTERS

Character	F_2	
	Phenotype	No. of individuals
Stem solidness	Solid	336
	Semi-solid	1489
	Hollow	1231
	Total*	3056
Seed length	Long	1877
	Short	1086
	Total	2963
Seed colour	Red	2315
	Amber	599
	Total	2914
Brush length	Long	1295
	Short	1676
	Total	2971

* Variations in totals due to inability to classify certain plants owing to sterility, shrunken seeds, etc.

Results from the tests of independence or association between solid stem and the other characters studied are presented in Table 3. The association between solid stem and dense spike was very high. While 25 F_2 plants were classified as having solid stems and lax spikes, no F_3 lines having this recombination were obtained. Four of the 25 plants were completely sterile. Seed from the balance was sown in F_3 lines. Nine of these were homozygous for dense spike and had evidently been wrongly

classified in the F_2. These plants were noted to have been severely attacked by common root rot in the F_2 and it is possible that the presence of this disease affected the expression of spike density. Similar effects due to bunt have been noted by Aamodt *et al.* (1). Eight of the F_3 lines segregated into hollow-stemmed lax-spike and solid-stemmed dense-spiked plants. These were the exceptional lines referred to above. Many plants in these lines were sterile. One line bred true for solid stem and lax spike but was sterile and two lines failed to germinate.

TABLE 3.—X^2 TEST OF INDEPENDENCE AND ASSOCIATION BETWEEN STEM-SOLIDNESS AND OTHER CHARACTERS IN THE F_2 OF THE CROSS R.L. 1097 × GOLDEN BALL

Stem solidness and	X^2	P lies between
Spike density	172.50	>.01
Seed length	1.94	.30 and .50
Seed colour	8.44	.01 and .02
Brush length	7.24	.02 and .05

While spike density is of no economic significance, results from similar crosses (2) have shown that the complete durum condition of spike density never appeared in 21-chromosome segregates. Therefore, the complete association between solid stem and spike density indicated that it would be impossible to obtain solid-stemmed lines with a chromosome number of 21.

Stem solidness was also found to be associated with amber seed colour and short brush but in both cases substantial numbers of the desired recombinations were obtained in the F_2 and later generations.

In the F_3 and later generations, solid-stemmed lines were selected that had vulgare-like seed characters. Eventually, 46 F_7 lines were obtained that had solid stems, dense spikes and vulgare-like seeds. None of the lines had seeds entirely vulgare-like but they were similar to the vulgare type in colour and brush length and were somewhat similar in length and shape. While these lines were entirely fertile, they lacked vigour. In comparative trials, the best line yielded less than either parent.

The reaction of some of these lines to certain diseases is presented in Table 4. No difficulty was experienced in combining the stem rust resistance of R.L. 1097 with the solid stem of Golden Ball. Three out of the 9 solid-stemmed lines tested were as resistant as the resistant parent. Both parents were resistant to leaf rust and no evidence of susceptibility was found in the 9 F_7 lines tested at Winnipeg nor in the 184 F_4 lines exposed to a natural leaf rust epidemic at Swift Current. The bunt reaction of the F_7 lines tested showed that they were as resistant or almost as resistant as the resistant parent. This would indicate an association between solid stem and bunt resistance. Further evidence in support of this is supplied by results from the test of 184 solid-stemmed F_4 lines. Only 7 of these were as susceptible as the susceptible parent, whereas 99 were as resistant as the resistant parent.

TABLE 4.—REACTION TO CERTAIN DISEASES OF F_7 LINES FROM THE CROSS R.L. 1097 × GOLDEN BALL

Hybrid No.	Stem rust	Leaf rust	Bunt infection
			%
H-41-143	Seg.*	R	3.0
-144	R	R	0.0
-145	MR	R	2.5
-146	R	R	5.0
-147	MS	R	1.5
-148	Seg.	R	1.5
-149	Seg.	R	2.0
-150	R	R	4.0
Golden Ball	MS	R	1.3
R.L. 1097	R	R	14.0

* The reactions designated by the symbols are as follows:
R Resistant
MR Moderately resistant
MS Moderately susceptible
Seg. Segregating.

When examined cytologically, all of the 46 F_7 lines were found to have a haploid chromosome number of 14. Behaviour in all cases, except one, appeared to be regular.

From the cross Regent × Golden Ball, an F_2 population of at least 25,000 plants was produced. All plants having lax spikes were selected and examined for solidness. Fourteen plants were found that had solid stems and lax spikes. Again, however, due to segregation and sterility, no F_3 lines were obtained that had this recombination of characters.

DISCUSSION

The solid-stemmed derivatives from the two crosses were preponderantly durum-like in appearance but through rigorous selection solid-stemmed derivatives were obtained that had various vulgare characteristics. The seed samples of many lines were much more vulgare-like than they were durum-like and certain of these exhibited the stem rust resistance of the vulgare parent. All, however, had dense spikes and a haploid chromosome number of 14. The vulgare characteristics that were combined with solid stem must, therefore, have been determined by genes located in the A or B genom or else by genes from the C genom incorporated in the A or B genom through translocation.

The failure to obtain solid-stemmed vulgare segregates lends support to Yamashita's hypothesis (13) that there exists a gene O_D for hollowness in the C genom that is epistatic to all other genes for solidness. Nevertheless, solid-stemmed varieties of *T. vulgare* do exist. Dr. Frankel of the Wheat Research Institute, Christchurch, New Zealand, states[3] "Solid stemmed wheats of *Triticum vulgare* are common in the Western Mediterranean countries, viz., Spain, Portugal, Algiers, Tunis and Morocco." Certain of these wheats obtained from these countries by Dr. Frankel and later obtained from him by this Station, have been studied for some years,

[3] Personal Communication.

Platt (10) and Platt *et al.* (11). The type of solidness exhibited by these varieties differs in two respects from that of Golden Ball. The vulgare solidness is more easily modified by environmental conditions and, under conditions that do not allow for maximum expression of solidness, they show hollowness just below the spike, whereas the durums are invariably solid at this point and show hollowness in one of the lower internodes. How such solid stemmed vulgare wheats originated cannot be stated at the present time. If they are derivatives from crosses between *T. vulgare* and *T. durum* or *T. turgidum*, then segmental interchanges between semi-homologous chromosomes must have taken place, in view of the results obtained by Yamashita and those obtained in the present investigation.

Despite their somewhat lower sawfly resistance, these solid-stemmed vulgare wheats offer much more promise as a source of resistance to this insect than does Golden Ball in breeding programs designed to produce agronomically desirable, sawfly resistant, vulgare wheats. In fact, it appears impracticable to attempt to transfer the solid-stem character and consequently the sawfly resistance of Golden Ball to vulgare wheats by hybridization. This is in marked contrast to the situation that exists with stem rust reaction where the durum resistance can be transferred to vulgare types without undue difficulty, Hayes *et al.* (4) and Peterson and Love (8).

SUMMARY

Crosses were made between Golden Ball, a solid-stemmed variety of *T. durum* ($n = 14$), and R.L. 1097 and Regent, hollow-stemmed varieties of *T. vulgare* ($n = 21$). In the former cross some 3,000, and in the latter some 25,000 F_2 plants were studied. Derivatives were found that had the solid-stemmed character of Golden Ball combined with certain seed characters and disease reactions of *T. vulgare*. However, all these lines had a haploid chromosome number of 14. It is concluded that it is not practicable to attempt to transfer the solid-stem character from *T. durum* to *T. vulgare* by hybridization.

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BROWN ROT AND OTHER FUNGAL WASTAGE IN HARVESTED PEACHES[1]

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In the five seasons which have elapsed since the first report (3) on brown rot investigations at the St. Catharines laboratory, the Niagara peach industry has twice been confronted with serious outbreaks of brown rot, once in 1940 and again in 1942. In the remaining three seasons brown rot has not been commonly regarded as serious, nevertheless, it has caused wastage in the packs under observation, and presumably in commercial packs also. In view of the current interest in the subject, it is considered advisable to make available the additional information accumulated since 1938. The present paper deals with the comparative incidence of brown rot and other rots in harvested fruit, as affected by various spray schedules, by refrigeration for different periods, and by other factors, during the years 1938 to 1942, inclusive. Some of the data were derived from experiments designed to determine the relative efficiency of different spray materials and some from experiments designed primarily as storage trials, carried on in co-operation with the Fruit and Vegetables Division of the Dominion Marketing Service.

The basic spray program followed were the "3-spray" and "4-spray" schedules, the former ending with an application 2 or 3 weeks before harvest, and the latter with a pre-pick spray just before harvest. On two occasions a 1-spray schedule, at harvest or 3 weeks before, was also used. The complete list of schedules and materials is given in Table 1, but not all of these materials were used every year.

TABLE 1.—PEACH SPRAY SCHEDULES

Application		Materials used					
	Pre-blossom shucks	Kolo-form	Kolo-fog*	Bartlett's Standard Wettable	Lime-Sulphur 1-50	C.O.C.S.	Lime-Sulphur 1-50
3-spray schedule	Shucks	Kolo-form	Kolo-fog	Bartlett's Standard Wettable Sulphur		Aero Sulphur	None
		with lead arsenate, zinc sulphate and lime					
4-spray schedule	3 weeks before harvest	Kolo-form	Kolo-fog	Bartlett's Standard Wettable Sulphur		Aero	Sulforon
	Pre-pick	Kolo-pick or Dust	Kolo-pick or Kolo pre-pick	Bartlett's pre-pick or Dust	Ferrox Flotation Sulphur	Aero	Sulforon

* Or Kolo-fog extra.

[1] Contribution No. 752 from the Division of Botany, Science Service, Department of Agriculture, Ottawa Canada.
[2] Plant Pathologist.

The peaches for the spray trials were wrapped in tissue and packed in open lugs in 1938-39, but from 1940 on they were packed without wrapping. The peaches for the storage trials were packed each year unwrapped in open lugs. Since the quantities of fruit placed in the cold room at any one time were relatively small, cooling took place much more rapidly than it would in commercial car-loadings in iced cars, without pre-cooling. In most cases, the experimental lots reached the temperature of the store overnight. While the fruit used for this purpose was obtained only from sprayed blocks, the peaches from the different blocks were not kept separate. In each experiment an attempt was made to select fruit of fairly uniform ripeness using ground-colour as a guide. The riper and greener fruit were either culled out or made up into separate packs and followed through separately. As no artificial inoculations were made, any infections were the result of natural dissemination of inoculum, and in this respect the packs were essentially similar to commercial ones.

The various lots were examined at intervals and at each examination rots were classified as incipient, brown rot, Rhizopus or other rots, then counted and discarded. Fruits classified as having incipient rots were usable, having only small spots up to about one-half inch in diameter. The incipient rots were disregarded in the count for the day on which they were observed but were counted in with the brown rot of the next examination, unless obviously caused by *Rhizopus nigricans*, in which case they were counted with the Rhizopus rots for the day. Fruits attacked by brown rot and overrun by Rhizopus were counted as having brown rot. The other rots were caused by miscellaneous fungi, including *Penicillium* spp., *Alternaria* spp. and *Cladosporium* spp. Wastage from rots of this type is not of commercial importance as it usually occurs only after the peaches have been held until they are no longer edible.

Experiments in 1938

The regular storage trials with the varieties, Rochester, Vedette, Valiant and Elberta, in which the storage periods ranged from 6 to 16 days at 45° F. and from 10 to 28 days at 33° F., were supplemented by storage trials conducted in connection with the spray trials with Rochester and Elberta. In the supplementary tests with the Rochester variety triplicate packs were made from each plot of the spray experiment. One pack from each plot was held at room temperature, one for 5 days at 45° F. and one for 1 day at room temperature and 4 days at 45° F., to determine the effects of delayed cooling. In the corresponding experiment with Elberta, the storage periods were 8 and 7 days at 45° F., with immediate storage and 1-day delay, respectively, except in the case of two plots which were picked 1 day earlier and in consequence had 1 and 2 days delays. The trends in the Elberta trials only are given (Figures 1 and 2) but they illustrate the behaviour of the other varieties under similar conditions. Several points of interest may be noted.

(1) Successive new infection centres continued to appear during the time the fruit was held at room temperature, indicating that the spore populations on different individual fruits did not germinate all at one time. It is probable that each fruit had its own spore load at picking time, as the

greater rate of incidence of rots after the sixteenth day in the unwrapped peaches held 9 days at 45° F. than in the comparable wrapped fruit of the spray trials suggests that the transfer of spores from the earlier affected areas to sound fruits was reduced to a minimum by wrapping.

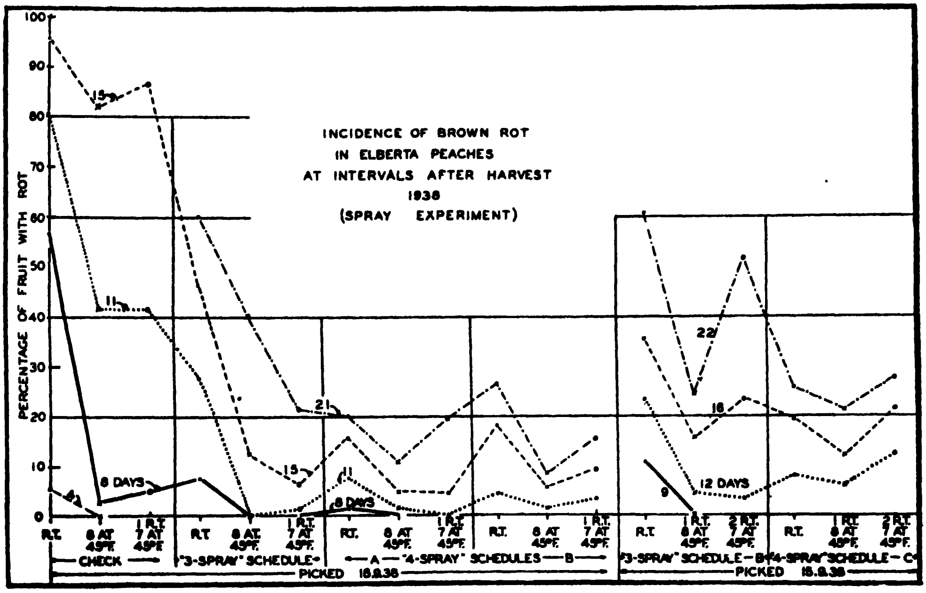

FIGURE 1. Incidence of brown rot in 1938 in Elberta peaches held at room temperature and after storage at 45° F. for 7 or 8 days, with no delay or with delays of 1 or 2 days at room temperature before cooling. In all figures, the numeral above each curve signifies the number of days after picking. The points in any one curve indicate the cumulative incidence of rot in the various lots examined on a given day.

(2) Little or no rot developed in sprayed peaches during the first 19 days of storage at 45° F. or the first 10 weeks at 33° F. The advantage

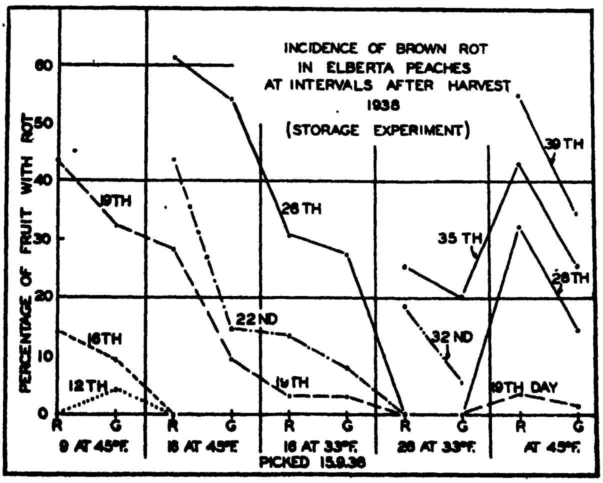

FIGURE 2. Incidence of brown rot in 1938 in Elberta peaches during storage at 45° F. and at room temperature after 9 or 16 days storage at 45° F. and after 16 or 28 days storage at 33° F. R. and G. represent riper and greener grades, respectively.

of the lower storage temperature in the control of brown rot was also reflected in the fact that the *greener* lots held 16 days at 45° F. showed a higher percentage of rot at successive examinations than did the *riper* lots held 16 days at 33° F. Furthermore the incidence of brown rot was about the same after 22 days of continuous storage at 45° F. as after 16 days at 33° F. and 6 days at room temperature.

(3) Comparison of the data for 9 and 16 days' storage at 45° F. and 16 and 28 days' storage at 33° F. suggests that the rate of incidence of brown rot after the return of the peaches to room temperature tends to be increased by prolonging the storage period at either low temperature.

(4) After removal from refrigeration, rot infections usually made their appearance sooner in the lots which were held 1 or 2 days before cooling than in those cooled on the day of picking.

(5) Wastage caused by *Rhizopus nigricans*, which is not shown in the figures, varied in importance in the different packs but was not serious in any lot during the first 2 weeks after harvest. This trouble did not devélop in cold store. There was no evidence that it could be controlled by spraying. Once started it spread rapidly from fruit to fruit forming "nests" of decay.

TABLE 2.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1938

Variety	"3-spray" schedules					"4-spray" schedules				
	Last spray	Rainfall		Control indices*		Last spray	Rainfall		Control indices	
		Time†	Amount	1st week‡	2nd week‡		Time	Amount	1st week	2nd week
			inches					inches		
Rochester	14†	11 6–7 1	.44 2.88 .17	68–87	80	4	1	.17	65-89	78-93
Elberta	22	13 9 5 4 2 1	.07 .71 .07 .12 .27 .07	80–86	52–57	6	5 4 2 1	.07 .12 .27 .07	97–100	78–84

* The control index, or reduction in incidence as result of treatment was calculated from the formula $C = 100 \frac{(c-s)}{c}$ where C = control index; c = percentage of rot in unsprayed and s in sprayed lots. † Time in days *before* harvest. ‡ *After* harvest.

In 1938 because of better weather at harvest the incidence of brown rot was considerably lower in Rochester than in Elberta. The various spray materials and schedules gave very good control (Table 2) during the first two weeks after picking. The falling off in the control indices for the "3-spray" schedule during the second week of the Elberta experiment was probably due to the series of showers just before harvest as well as to the longer time between spraying and picking.

Experiments in 1939

Data for the spray and storage trials in 1939 are given in Table 3 and Figure 3. The Rochester variety suffered more severely from brown rot than the other varieties in 1939. On the whole the spray programs were considerably less effective than in 1938. The longer time between the last spray of the "3-spray" schedule and harvest and the frequent heavy showers in the interval probably account for this.

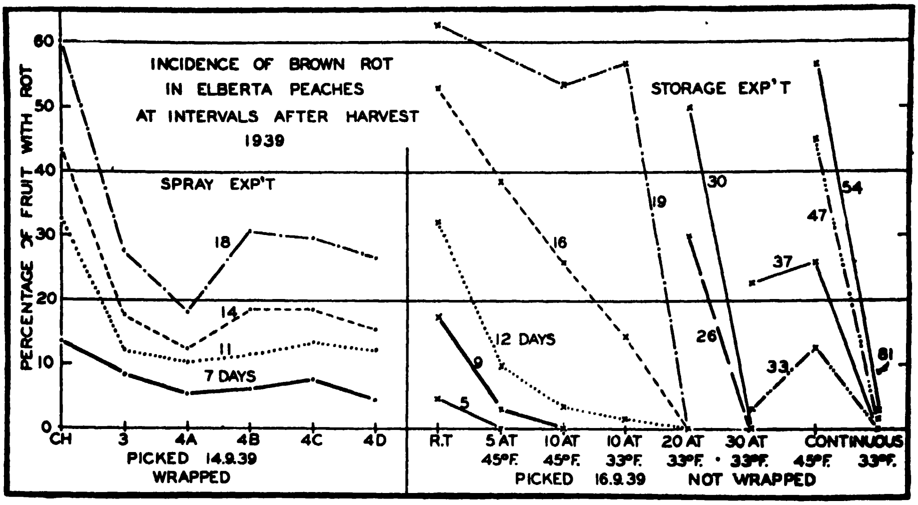

FIGURE 3. Incidence of brown rot in 1939 in Elberta peaches. In the spray experiment 3 indicates the "3-spray" schedule and 4A, 4B, 4C, 4D, different "4-spray" schedules. In the storage experiment, the storage periods are 5 to 10 days and continuous storage at 45° F. and 10, 20 and 30 days and continuous storage at 33° F.

TABLE 3.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1939

Variety	"3-spray" schedules					"4-spray" schedules				
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control indices	
		Time*	Amount	1st week†	2nd week		Time	Amount	1st week	2nd week
			inches					inches		
	21*	20	.22				4	.08		
Rochester		14	1.81	35.0	16.9	4	3	.17	82–91	60–80
		10	1.08				1	.30		
		3–4	.15							
		1	.30							
		25–26	.15							
		23	.30				5	.02		
Elberta	26	9–10	.40	38.0	59.0	5	4	.47	43–59	57–71
		7	.30				2	.20		
		4–5	.49							
		2	.20							

* Time in days before harvest. † After harvest.

The results of the 1939 storage experiments in most respects resemble those of 1938. Notable exceptions, however, were observed in the Elberta lot held 10 days at 33° F., in which more rot developed between the sixteenth and nineteenth days, than in the comparable lot from 45° F., and in the Rochester and Vedette lots held 21 days at 33° F. in which the incidence of brown rot was exceptionally high. Brown rot also appeared during continuous storage at both low temperatures earlier than in 1938.

Comparison of the rates of incidence in sprayed peaches at room temperature suggests that the later pick used for storage tests was more subject to brown rot than the earlier one used for the spray tests. That this was due more to the greater exposure to contamination of the unwrapped fruit of the storage trials than to inherent difference in susceptibility is supported by the evidence from an earlier pack used for storage trials. The data presented in Figure 3 are for the second storage run, the first being picked 5 days earlier. The incidence of brown rot in these two storage experiments showed that only a slight increase in the susceptibility of Elberta peaches occurred in the interval between the two runs. Strikingly similar results were obtained in similar trials with the Rochester variety.

Again Rhizopus infections did not become serious until the second or third week after harvest and then only in lots at or returned to room temperature.

Experiments in 1940

Weather conditions generally were very favourable for a buildup of brown-rot inoculum during the summer of 1940, so that peaches even when picked under apparently satisfactory conditions quickly developed a high percentage of wastage (Figures 4 and 5). Under less favourable harvesting conditions, the losses from brown rot were immediate and severe.

The spray experiments show very clearly (Table 4) that while the "3-spray" schedule was in itself of little value in controlling brown rot in a season when the disease was difficult to hold in check, it proved its worth when used in conjunction with the pre-pick spray. In this regard, the experiment with Elberta was particularly instructive, since the pre-pick spray as a single application was only 36.3% efficient while the same material as part of the complete "4-spray" schedule was 62% efficient. In both the Rochester and Elberta spray experiments, there was a decided loss in the efficiency of the "4-spray" program during the second week after harvest. While the long lapse of time between the two last sprays of the schedule for Elberta was undoubtedly a contributing factor, the Rochester experiment (Table 4), in which the sprays were more normally timed, suggests that a considerable part of this loss in efficiency could be attributed to the fact that none of the peaches were wrapped in 1940. In this connection it should be noted that, in contrast with 1939 experience, there was little difference in the incidence of rot between the Elberta peaches held at room temperature for the storage trial and those receiving the "4-spray" schedule in the spray trial. In the experiments with the Rochester variety, the storage lot at room temperature behaved much the same as the "3-spray" lot in the spray tests.

TABLE 4.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1940

Variety	"3-spray" schedule					"4-spray" schedule					Pre-pick only	
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control indices		Control indices	
		Time*	Amount	1st week†	2nd week†		Time	Amount	1st week	2nd week	1st week	2nd week
			inches					inches				
		25–26	1.16									
		18	.20									
		12	.65									
Rochester	29*	9	.04	9.0	3.7	2	1	.30	40–65	18–43	—	—
		5	.09				0	.05				
		3	.03									
		1	.30									
		0	.05									
		18–44	2.52									
Elberta	47	17	.47	—	—	2	0	0	60–62	15–17.5	36.3	5.3
		3	.62									

* Days before harvest. † After harvest.

Although in the storage trials (Figures 4 and 5) rots tended, both during and after refrigeration, to develop earlier than in other years, the relations between the various treatments followed fairly well the pattern

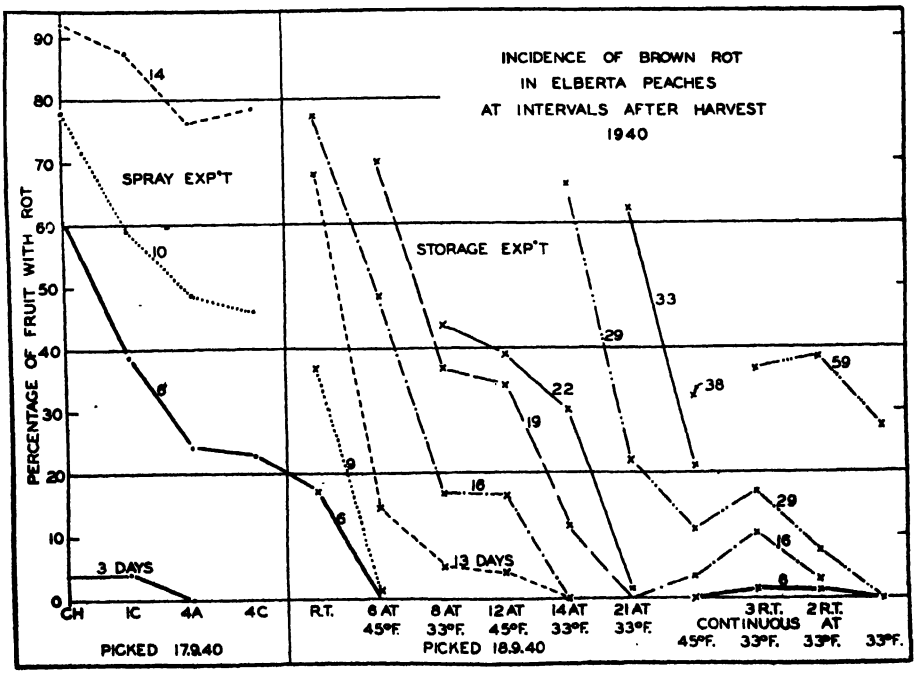

FIGURE 4. Incidence of brown rot in 1940 in Elberta peaches. 1C indicates pre-pick spray only and 4A and 4C, the "4-spray" schedules. Storage periods are 6 and 12 days at 45° F. and 14 and 21 days at 33° F. 3R.T. and 2R.T. signify 3 and 2 day delays at room temperature before storing at 33° F.

already outlined. Some lots of both Carmen and Elberta varieties were held 1 to 3 days at room temperature before being subjected to continuous refrigeration at 33° F. With both varieties the effects of delayed cooling on the onset of brown rot were noticeable during the first week or so of storage but were much more striking in the Carmen tests, partly because of higher temperature and humidity during the delay period and partly because of hail marks which were also to some degree responsible for the generally high incidence of brown rot in that variety. The first wave of rot in the lots cooled 3 days after picking were obviously the result of infections occurring early in the holding period at room temperature. Infections initiated towards the end of the 3-day delay or during the 1-day

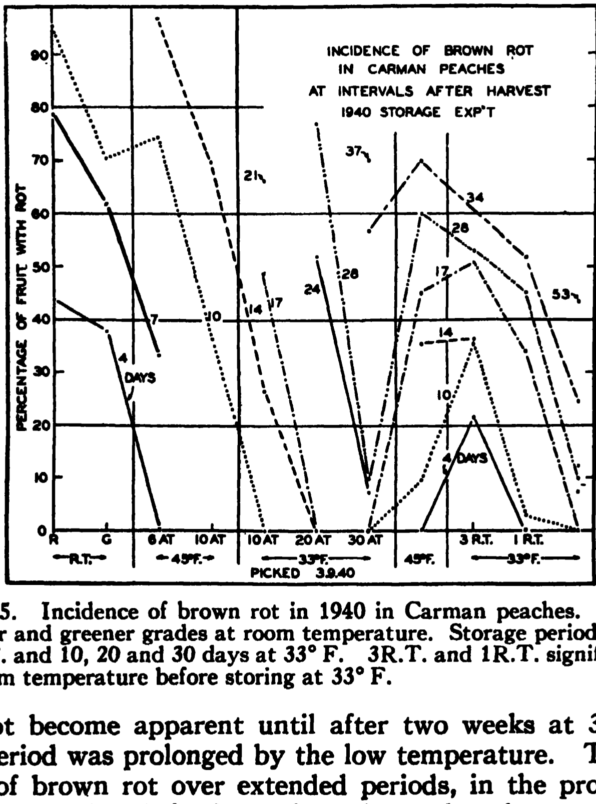

FIGURE 5. Incidence of brown rot in 1940 in Carman peaches. R. and G. at R.T. are riper and greener grades at room temperature. Storage periods are 6 and 10 days at 45° F. and 10, 20 and 30 days at 33° F. 3R.T. and 1R.T. signify 3 and 1 day delays at room temperature before storing at 33° F.

delay did not become apparent until after two weeks at 33° F., as the incubation period was prolonged by the low temperature. The successive occurrences of brown rot over extended periods, in the promptly cooled lots, demonstrate that infection takes place, though very slowly, even at 33° F.

Wastage from Rhizopus infection was negligible except in the Elberta storage experiment where it appeared 10 to 14 days after removal from the cold.

Experiments in 1941

In 1941, the incidence of brown rot for the first week after harvest, was low (8.9% for unsprayed Rochester and 4.8% for unsprayed Elberta) and the results of the spray tests were, in consequence, inconclusive. Comparatively little brown rot was observed in the storage experiments but Rhizopus rot was severe after the first 7 to 10 days at room temperature.

Experiments in 1942

Frequent rains and prolonged periods of high humidity during the greater part of the summer of 1942, as in that of 1940, set the stage for an outbreak of brown rot which culminated in a disastrous week during Elberta harvest. In spite of the fact that the Elberta peaches used for experimental purposes were picked under comparatively favourable conditions, just before the wet spell responsible for the major outbreak, a comparatively high percentage of brown rot developed (Figure 6). The Rochester pack also showed large amounts of brown rot in unsprayed lots.

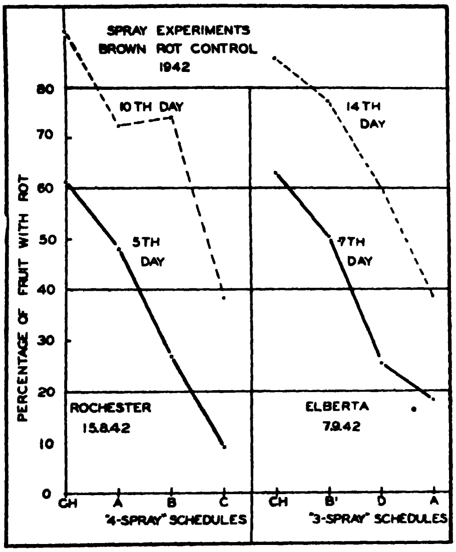

FIGURE 6. Incidence of brown rot in 1942 in Rochester and Elberta peaches. A, B, C and D represent different spray materials. B[1] indicates a single spray 18 days before harvest.

TABLE 5.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1942

Variety	"3-spray" schedule					"4-spray" schedule					Single spray	
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control Indices		Control indices	
		Time*	Amount	1st week†	2nd week†		Time	Amount	1st week	2nd week	1st week	2nd week
			inches					inches				
		14	.28									
		12	.14									
		10	.25									
Rochester	16*	4	.12	—	—	2	2	.04	21.2	18.7	—	—
		3	1.00				1	.23	to	to		
		2	.04						85.5	57.7		
		1	.23									
		15	.14	59.2	29.6							
				to	to	—	—	—	—	—	19.6	9.8
Elberta	18	10–11	.18	70.8	54.8							

* Days *before* harvest. † After harvest.

On the whole, the response to spraying (Table 5, Figure 6) was fairly satisfactory considering the rainfall between the third and fourth sprays in the Rochester trial and the lack of a pre-pick spray in the Elberta trial. In its effects, the "3-spray" schedule program used for Elberta compared favourably with the "4-spray" schedule in the Rochester experiment, partly because of the difference in the amount of rainfall in the 2 weeks before harvest and partly because of an accidental wetting of some of the Rochester pack, which reduced the effectiveness of the spray materials almost in proportion to the extent of the wetting. As a result of this occurrence the spray material most efficient in controlling brown rot in the Elberta variety gave the poorest control with the Rochester.

The low control index for the "single spray" applied 18 days before harvest, as compared with the indices for the "3-spray" schedule, again demonstrates the importance of the earlier applications of the recommended progam, viz., the pre-blossom and shucks sprays.

Two experiments in the control of brown rot by means of sodium bisulphite tablets were also conducted. This method originated in South Africa (1, 2) for the control of moulds in packed grapes. These tablets, made up of 2 parts powdered anhydrous aluminium sulphite to 3 parts powdered sodium meta-bisulphite granulated with spermaceti, slowly evolve sulphur dioxide as they absorb water vapour. They were supplied in five sizes ranging in weight from 0.055 gram to 0.88 gram each, in doubling geometric progression. In the brown rot experiment, the tablets were wrapped singly in a piece of paper towel and distributed among unsprayed peaches at the rate of 1 to 4 of the larger sizes and 3 to 6 of the smaller sizes per 11 qt. basket.

TABLE 6.—EFFECTIVENESS OF SODIUM META-BISULPHITE TABLETS IN THE CONTROL OF BROWN ROT IN UNSPRAYED PEACHES AT ROOM TEMPERATURE, IN 1942

Tablet size	Rochester variety*					Elberta†
	1 tablet	2 tablets	3 tablets	4 tablets	6 tablets	3 tablets
.88 gm.	—	52.3†	—	65.0	—	22.4
.44 gm.	13.8	—	55.0	—	—	—
.22 gm.	28.5	26.1	44.0	—	—	10.9
.055 gm.	—	—	20.4	31.2	21.2	− 9.6

* Percentage brown rot in checks:—Rochester, 70.5; Elberta 63.1.
† Control index.

As indicated in Table 6, the tablets did effect some reduction in the amount of brown rot, which, with three exceptions, varied according to the size and number of the tablets used. While they were not as efficient as the conventional spray schedules, the tablets could be used under outbreak conditions to supplement spraying were it not for the fact that the larger tablets caused considerable injury. Under the conditions of the experiment from 5 to 22% of the fruits in a basket were damaged. Affected tissue appeared to have been "fixed" and partly bleached by the action of the chemical, and was delimited by a thin brown zone, forming in individual fruits a section of a sphere centred at the tablet.

DISCUSSION

It has long been recognized that weather conditions, particularly precipitation and humidity, coincident with harvest are of major significance in determining the severity of outbreaks of brown rot. But the

TABLE 7.—RAINFALL AND AVERAGE HUMIDITY FOR THE SUMMER MONTHS

Month	Rainfall						Rel. humidity (12 hr. av.)					
	14 yr. av.	1938	1939	1940	1941	1942	A.M.			P.M.		
							1940	1941	1942	1940	1941	1942
May	2.63	2.28	0.81	4.22	0.47	5.33	79.3	67.0	75.6	69.4	53.5	66.3
June	2.39	1.54	1.44	2.96	1.50	1.57	78.1	70.5	74.5	66.6	59.1	63.4
July	2.50	2.69	3.22	2.64	4.39	3.68	—	71.3	71.9	—	59.5	57.2
August	2.26	4.16	3.56	2.51	1.70	2.15	79.8	70.7	74.8	70.6	55.3	62.8
September	2.49	1.43	2.94	2.75	0.59	3.16	81.3	71.5	75.0	73.3	55.9	60.4
Average	2.45	2.42	2.39	3.02	1.73	3.18	79.7	70.1	74.5	70.1	56.7	62.4
Total June-Aug.	7.15	8.39	8.22	8.11	7.59	7.40	—	—	—	—	—	—

TABLE 8.—NUMBER OF DAYS ON WHICH RELATIVE HUMIDITY EXCEEDED 80% FOR 12 HOURS OR MORE, FOR 6 TO 12 HOURS AND FOR 0 HOURS

Month	R. H. 80% for 12 hrs. or more				R. H. 80% for 6 to 12 hrs.				R. H. not over 80%			
	1939	1940	1941	1942	1939	1940	1941	1942	1939	1940	1941	1942
May	5	15	3	11	9	8	8	8	6	2	11	2
June	5	9/23	5	8	13	6/23	7	15	3	3/23	6	0
July	2	—	7	4/23	13	—	4	7/23	1	—	5	2/23
August	10	10/26	2	9	14	11/26	9	10	1	1/26	6	4
September	8/25	18/27	2/22	5/23	6/25	5/27	10/22	9/23	1/25	0/27	5/22	2/23
Total	30	52	19	37	55	30	38	49	12	6	33	10
	148*	107	145	138	148	107	145	138	148	107	145	138

* Denominators, where used, indicate the number of days for which records were available.

foregoing experiments would suggest that the weather of the earlier part of the season may have considerable influence on the control of the disease through its effect on spore load and possibly on the inherent susceptibility of the fruit, giving rise to what might be termed the basic incidence for the season. For example, in 1940 when unsprayed peaches picked under favourable conditions were abnormally subject to brown rot, a high basic incidence may be postulated. In that year, the rainfall in May (Table 7) was much above normal, the average humidity was high and on 15 days relative humidity exceeded 80% for periods of 12 hours or more (Table 8). Conditions at blossom time were favourable for blossom blight and, though rainfall was not excessive in June, July and August (Table 7), the summer was characterized by frequent showers and protracted periods of damp

weather in which there was ample opportunity to build up inoculum. Except that conditions at blossom time were much better, the season of 1942, though less extreme, was similar to that of 1940, resulting in a moderately high basic incidence. In both years, as already mentioned, omission of the early sprays brought about a pronounced drop in the efficiency of the final spray application. Furthermore, since the "shucks" spray was dropped from one of the 1942 Elberta schedules with little or no loss of control, it may be concluded that under the conditions of the experiment and in spite of little blossom blight, the "blossom" spray was more important in brown rot control than "shucks" spray, which is primarily for curculio and scab. In 1939 and 1941, blossom blight was not a factor and in 1938, 1939 and 1941, drying days alternated more regularly with damp ones so that there was less opportunity for inoculum to accumulate. In these years, when one or other of the varieties tested showed comparatively small amounts of brown rot in unsprayed fruit during the first week after harvest and the basic incidence was presumably low, the brown rot losses in Elberta in 1938 and in Rochester in 1939 were attributable to unfavourable conditions just before or during harvest when a rapid local increase in the quantity of inoculum could and probably did take place.

A comparison of the control indices, Tables 2 to 5, suggests that control by spraying, as might be expected, was more difficult in years of high basic incidence. This was particularly true of the 1940 season. However, the effectiveness of a spray program may also be modified by other factors such as sulphur content, particle size, and adhesive properties of the spray materials, coverage, timing of sprays, amount and nature of precipitation between spraying and harvest, harvesting conditions, wrapping of the fruit, etc. Evidence of the operation of some of these factors has already been noticed in the reports on individual experiments, but from the data in hand, it is difficult to assess their relative significance or to account satisfactorily for all the fluctuations in efficiency. Suffice it to say, that, in general practice, the long-range unpredictability of local weather and the possibility of narrow margins, between favourable and unfavourable harvesting conditions makes it necessary to apply all the recommended sprays as an insurance measure and to time the third spray at no more than 3 weeks and the pre-pick spray 1 or 2 days before harvest is expected. As the sprays are more fungistatic than fungicidal and therefore tend to delay rather than to prevent infection, spraying should not be looked upon as a substitute for other precautions. For example, peaches should not be handled while they are wet nor allowed to get damp after being picked and the necessary precautions should be taken to minimize the possibilities of contamination during picking and packing, if satisfactory control of brown rot is to be achieved.

With regard to refrigeration of peaches, these experiments have shown that infection by brown rot can take place at temperatures as low as 33° F., even though the incubation period is long. Ordinarily, temperatures of 45° F. or lower will delay infection long enough for commercial purposes, but it is of interest to note that the rate of incidence of brown rot after removal from the cold tends to drop with the lower refrigerating temperature and to rise with the longer refrigeration period. If, however, the initial stages of infection have already taken place before the fruit is chilled,

the advantages of refrigeration are likely to be lost. For this reason, the importance of the careful selection of disease-free fruit and prompt packing and cooling cannot be overemphasized, especially in seasons when the basic incidence is likely to be high. In such years, pre-cooling the pack before refrigeration for the rapid removal of field heat is highly to be recommended. By the same token, efforts should be made to have peaches promptly despatched and rapidly distributed, where shipping without refrigeration is in order.

SUMMARY

1. In the years 1938 to 1942, inclusive, a 4-spray schedule, comprising sprays early in blossom time, at shuck fall, 2 to 3 weeks before harvest and just before picking reduced brown rot incidence during the first week after harvest by 40 to 65% in the worst years and by 65 to 100% in other years.

2. In view of the possibility of a rapid build-up of inoculum at any time during the growing season, omission of any of the sprays in the regular schedule is likely to reduce the efficiency of the spray program.

3. Wrapping peaches in tissue tends to add to the effectiveness of spraying by reducing chance contamination in the pack.

4. Infection can take place at temperatures as low as 33° F. but the incubation period is greatly prolonged so that, for practical purposes, prompt refrigeration at or below 45° F. is satisfactory. In long distance shipping where transportation exceeds one week a temperature of 33° F. is recommended. For shorter hauls 45° F. suffices.

5. The rate of incidence of brown rot during the first few days after removal to room temperature is lowered as the holding temperature in the cold store approaches 32° F. but tends to rise as the time in cold store lengthens.

6. Rot caused by black mould, *Rhizopus nigricans*, was not observed on peaches during refrigeration, but may be serious after storage. It seldom appeared in peaches at room temperature until the second week after harvest unless the pack was damp. It tends to spread from fruit to fruit to form nests of rot, to a greater degree than does brown rot. Rhizopus rot does not appear to be amenable to spraying.

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THE USE OF CORN GLUTEN FEED TO REPLACE MEAT MEAL IN POULTRY RATIONS[1]

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Corn gluten feed or gluten feed is a by-product of the starch and glucose industry. This feedstuff should be distinguished from corn gluten meal which is also a by-product of the same industry, the difference being that corn gluten feed usually contains between 23 and 25% protein, whereas corn gluten meal will contain around 40 to 45% protein.

Corn gluten feed has been used successfully in rations for beef cattle, horses, sheep and swine and it is one of the commonest protein supplements used in the feeding of dairy cattle. Sloan (4) has indicated that although corn gluten feed may be used in poultry rations, it is not as satisfactory a protein concentrate as soybean oil meal.

According to Morrison (1), the quality of the protein of corn gluten feed is similar to that of corn and therefore is deficient in at least two essential amino acids, namely, lysine and tryptophane.

I. THE USE OF CORN GLUTEN FEED AS A PROTEIN SUPPLEMENT IN A RATION FOR GROWING CHICKS

This experiment was conducted to determine the extent to which corn gluten feed can be used to replace meat meal in a good chick starting ration. Eight groups of birds were used, each group being composed of 34 Barred Plymouth Rock chicks, half of which were pullets and half cockerels. The general experimental procedure and the details of management and of the method of formulating the rations have been presented in an earlier paper (Pettit *et al.* (2)). In the present study, the feeding trials were continued for 10 weeks and the chicks were weighed at weekly intervals.

The composition of the basal mixture which was used for each 100 pounds of feed is presented in Table 1.

TABLE 1.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground oat groats	18.0
Ground yellow corn	18.0
Ground wheat	18.0
Cereal grass	1.0
Dehydrated alfalfa	2.5
Buttermilk powder	10.0
Salt*	1.0
Steamed bone meal	1.0
Oyster shell	1.0
Grit (insoluble)	1.0
Cod liver oil**	0.25
Total	71 75

* Contained 0.02% KI and 2.0% $MnSO_4 \cdot 4H_2O$.
** Contained 400 A.O.A.C. units of vitamin D and 3000 I.U. of vitamin A per gram.

[1] A contribution from the Departments of Poultry Husbandry and Animal Nutrition of the Ontario Agricultural College. J. Walker and E. C. Roberts assisted with the project and a part of the work reported herein was presented in their undergraduate thesis in partial fulfilment of the requirements for the Degree of Bachelor of Science in Agriculture (1943).

Table 2 shows the ration composition, mortality data, feed consumption and average live weight at 10 weeks of age for each group while the average weekly weights and gains are presented in Figure 1.

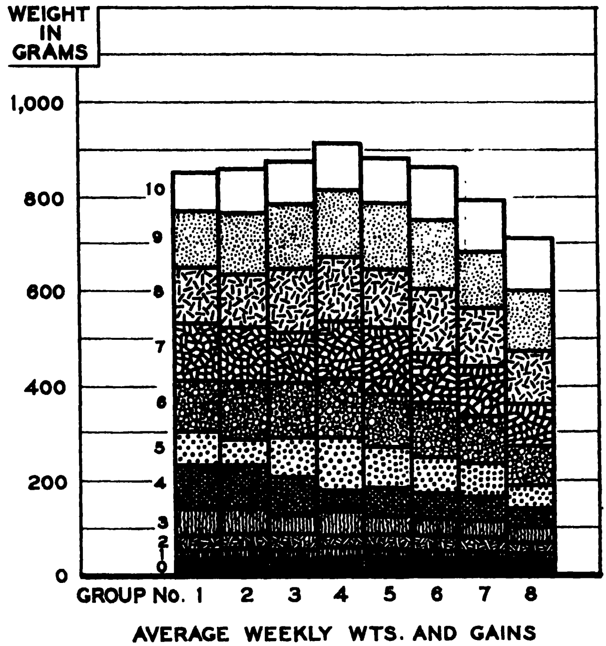

FIGURE 1.—AVERAGE WEEKLY WEIGHTS AND GAINS

TABLE 2.—CORN GLUTEN FEED IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.50	9.00	7.50	6.00	4.50	3.00	1.50	—
Ground barley (%)	17.75	16.25	14.75	12.25	8.75	7.25	4.25	2.25
Corn gluten feed (%)	—	3.00	6.00	10.00	15.00	18.00	22.00	26.00
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mortality	3	1	4	0	0	1	0	2
Feed consumption (lb.)	214.5	205.5	217.5	216.0	221.5	216.7	212.5	211.0
Average weight at 10 weeks (gm.)	848.0	860.8	885.1	910.2	879.4	858:4	789.9	707.8

The 10-week weight data were analysed for significance by the method of "weighted squares of means". This method, proposed by Yates (6), has been adapted for the interpretation of data from chick nutrition experiments by Titus and Hammond (5). Tests of significance were made by means of the F test (Snedecor (3)). Since the F value for diet exceeded the 5% point, it may be concluded that the weights were significantly different, therefore making further analysis necessary. By application of

the t test to the differences between the unweighted mean live weights of males and females on any two different diets, the results presented in Table 3 were obtained.

TABLE 3.—SIGNIFICANCE OF DIFFERENCE BETWEEN DIETS

Group No.	Significantly better than	Significantly poorer than
1	7, 8	3, 4, 5
2	7, 8	4
3	1, 7, 8	4
4	All	None
5	1, 7, 8	4
6	7, 8	4
7	8	All but 8
8	None	All

It will be noted in Figure 1 that, as the meat meal was replaced by corn gluten feed, there was a gradual increase in the maximum weights attained by successive groups 1 to 4 and a gradual decrease thereafter, indicating a decided optimum when the ration contained 10% of corn gluten feed and 6% of meat meal. When more than 18% of corn gluten feed was included in the ration (groups 7 and 8), the maximum weights attained were significantly lower than the control group (Table 3). This would seem to indicate that with such high levels of gluten feed replacing meat meal, the ration is rendered deficient in some nutrients (possibly amino acids) essential for most rapid growth.

As will be noted in Table 3, corn gluten feed in concentrations as high as 26% of the ration did not affect feed consumption, indicating that this feedstuff is not unpalatable to chickens. In addition, since no mortality resulted from feeding relatively high levels of corn gluten feed, it would appear to be quite a safe feed for chickens.

II. CORN GLUTEN FEED IN LAYING AND BREEDING RATIONS

This experiment was planned to evaluate corn gluten feed as a protein supplement in a layer-breeder mash. Four groups of 25 Barred Plymouth Rock pullets with 2 cockerels per group were used. The general experimental method used was described in a previous paper (Pettit *et al.*, (2)). The test period in the present case was 10 months. Egg production was recorded for the whole period, and hatchability was determined over a period of 3 months.

The basal mixture which was used for each 100 pounds of mash is presented in Table 4.

Mash was before the birds at all times and grain which regularly was fed before the birds went to roost was furnished on a per diem basis of 3½ lb. per group. The grain mixture consisted of 1 part oats, 1 part corn and 2 parts wheat. Oyster shell, grit and bone meal were fed *ad libitum* in a separate hopper.

TABLE 4.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground yellow corn	12.5
Crushed oats	18.0
Rolled oat groats	5.0
Ground wheat	13.0
Wheat middlings	5.0
Wheat bran	10.0
Wheat shorts	12.5
Ground barley	10.0
Soybean oil meal	7.5
Bone meal	1.5
Oyster shell	1.5
Molasses	2.25
Salt*	1.25
Total	100.00
$MnSO_4 . 4H_2O$	0.6 oz.

* Contained 0.02% KI.

The composition of the rations is shown in Table 5.

TABLE 5.—COMPOSITION OF THE RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4
	%	%	%	%
Basal	67.25	64.75	61.75	56.75
Ground yellow corn	10.75	10.75	10.75	10.75
Buttermilk powder	6.00	6.00	6.00	6.00
Meal meal	10.50	9.50	8.00	5.00
Corn gluten feed	—	3.50	8.00	16.00
Dehydrated alfalfa	5.00	5.00	5.00	5.00
Cod liver oil*	0.50	0.50	0.50	0.50
Total	100.0	100.0	100.0	100.0

* Contained 400 A.O.A.C. units of vitamin D and 3000 I.U. of vitamin A per gram.

TABLE 6.—CORN GLUTEN FEED IN LAYER-BREEDER RATIONS

Group	Egg production Nov. 1/41 to Aug. 31/42		Total fertile eggs set	*Hatchability Feb. 1/42 to April 30/42			
				Feb.	March	April	Average
	Total	%		%	%	%	%
1	4146	54	1178	70.3	66.9	57.0	64.5
2	3850	50	996	75.5	70.4	70.0	72.1
3	4177	55	1064	62.7	66.2	60.9	63.6
4	4512	59	1211	65.8	68.3	73.1	69.1

* Based on fertile eggs set.

Figure 2 shows the distribution of the embryonic mortality. Table 6 shows the egg production results for the 10 month experimental period and the hatchability results for the 3 months, February, March and April.

As shown in Table 6, there were only minor differences in egg production between groups. The hatchability results varied somewhat from

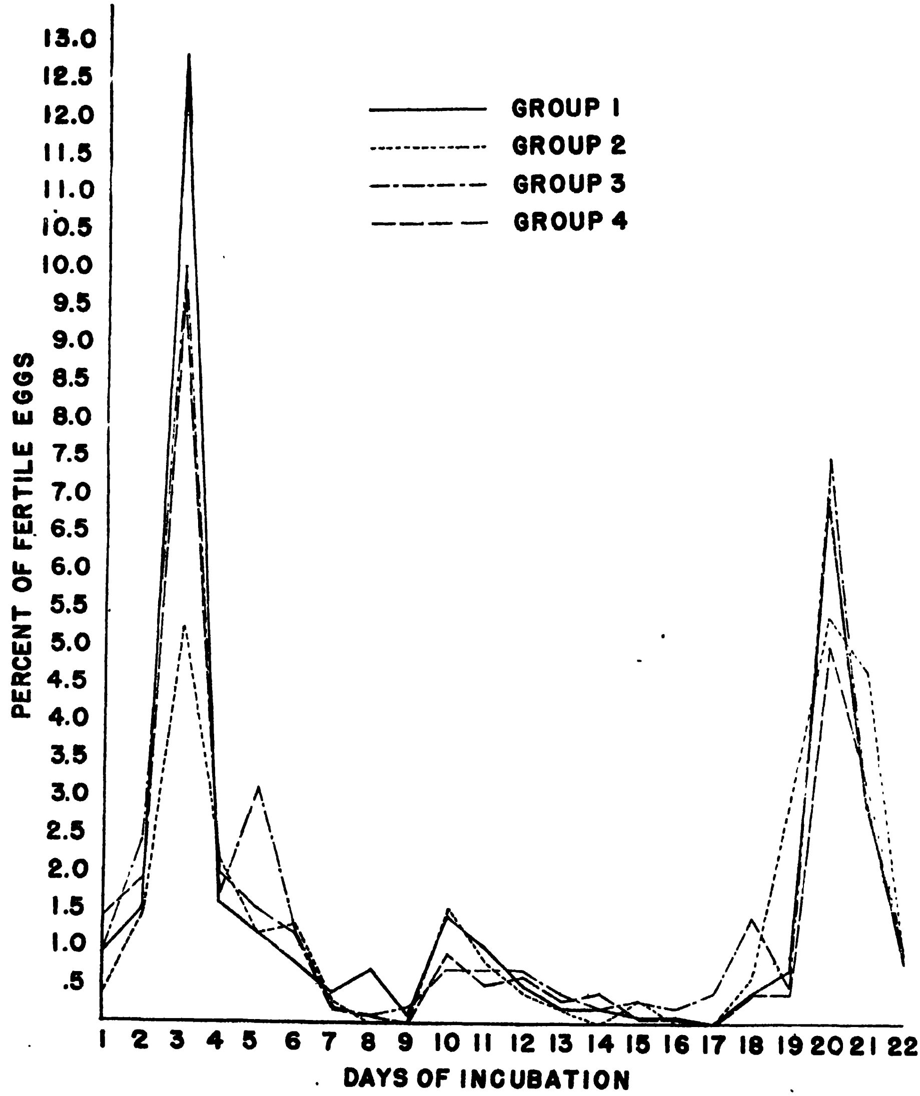

FIGURE 2.—DISTRIBUTION OF EMBRYONIC MORTALITY

month to month but the differences between the average hatchability figures are not great. The percentage hatchability of group 1 declined to a greater extent than that of groups 2 or 3 as the season advanced, while the hatchability in the case of group 4 showed some increase with the advancing season. This would seem to indicate that too high a concentration of meat meal in the ration is not desirable from the point of view

of maintaining hatchability throughout the season and that the substitution of up to half of the meat meal by corn gluten feed improves the ration considerably in this regard.

As indicated in Figure 2 all groups had high embryonic mortality peaks on the third, twentieth and twenty-first days, with comparatively little mortality at any other period of incubation. In comparison with the other groups, the third day peak for group 2 was low, while the control group had the highest mortality at this time. A monthly summary of this early incubation peak indicated certain trends— whereas the third day mortality was practically constant each month for group 2, that of groups 3 and 4 declined with advancing season and in the case of the control group there was a considerable increase in embryonic deaths at this time as the season advanced. In all groups, approximately 50% of the embryos dying on or after the eighteenth day of incubation were found to be in a malposition within the shell.

Since production and hatchability results are equally good when as much as 16% of corn gluten feed is included in the mash to replace meat meal as when none of the meat meal is replaced, it would appear that corn gluten meal is a satisfactory substitute for at least a part of the meat meal in a layer-breeder mash.

SUMMARY

Corn gluten feed was used as a vegetable protein supplement to replace meat meal in a ration for growing chicks and in a ration for laying and breeding birds. The meat meal was replaced by successively larger amounts of corn gluten feed until 26% was included in the ration to replace all of the meat meal in the chick starting ration and 16% was included to replace half the meat meal in the layer-breeder mash.

From the results of the growth trials it may be concluded that corn gluten feed is a suitable vegetable protein supplement to replace part of the meat meal in a ration for growing chicks. In such a ration as here employed, it may be used satisfactorily to form up to 18% of the diet, with an optimum at around 10%. When levels of 22 and 26% of corn gluten feed were used, the growth rate was somewhat reduced but the ration remained quite palatable and caused no mortality.

The results of the production and hatchability studies indicate that under the conditions of the experiment, corn gluten feed may be used in the mash to replace part of the meat meal on a protein equivalent basis in amounts up to 16%.

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LEVEL AND SOURCE OF PROTEIN IN POULTRY PRODUCTION

II. AS RELATED TO ECONOMICAL PRODUCTION OF EGGS[1]

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In a paper covering the rearing phase of this project (5) the comparative efficiency of different levels of protein from vegetable or animal sources averaging approximately 12.5%, 14.5% and 17% for the production of growth was determined. It was concluded that 12.5% of protein was too low and that, with reasonable supplementation by pasture, the intermediate level so closely approximated the highest level in results, actually surpassing it with respect to efficiency of use of protein and economy of production of body weight, that a saving of 2.5% of protein could safely be made in this way. It was realized that it was necessary to demonstrate that no ill effect of this lower protein level would be produced which might carry over into the period of egg production, and possibly nullify the value of the saving made during the rearing period. It had been originally planned that this project should include the egg production phase to determine whether levels of protein lower than those generally recommended might not be used for this purpose with equally as good results or with a sufficient degree of satisfaction to justify their use in a time of protein scarcity such as has been brought about by the present crisis. The plan of experiment involved an extension of the work of evaluation of supplementary vegetable protein as a substitute for the major proportion of the animal protein feeds of the ration, to cover the period of egg production. The experimental technique actually used in this experiment also made possible an assay of the comparative merits of the environmental conditions of the laying battery as opposed to the usual laying house method of management.

For a survey of the subject of protein and egg production, reference should be made to the recent review by Heuser (6). In general it seems to be conceded that within a reasonable range of protein levels, increased production may be expected as the level increases. If efficiency and economy are considered as well as absolute degree of production obtainable, however, it becomes obvious that an upper limit exists which is dictated by a proper balance between these factors. In general there is agreement that levels of protein in the neighbourhood of 12% would seem to be inadequate.

A large amount of research is on record dealing with the adequacy of soy bean meal as a substitute for animal protein ingredients of the ration. It seems obvious from a review of this work that this product requires some supplementation in the nature of both vitamin and protein additions. (1, 2, 4). Even with supplementation such a ration might not be efficient

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when fed to pullets which had been raised on a diet whose proteins came largely from a vegetable rather than animal source. This part of the present experiment was planned to obtain information in answer to this question.

EXPERIMENTAL

The pullets which were used in the rearing phase of this experiment were placed in laying quarters on November 1 at which time a small number of pullets in each of the medium and high animal protein groups as well as one pullet in the high vegetable protein group were laying. One-half of all birds was placed in laying batteries and the other half in laying house pens the division being made by random selection. At the beginning of the experiment there was a similar number of birds in the laying house and in the battery which had been reared on each of low, medium and high animal protein, and low, medium and high vegetable protein. In the laying house the birds were again divided at random to form alternate duplicate pens on each treatment, a technique calculated to increase the reliability of the results obtained through replication. The degree of agreement between such duplicates represents a rather exacting test of the reliability of the sampling technique as well as of the control of environmental conditions. All birds were randomized over 3 laying batteries of 3 tiers each according to treatment, battery and tier. In view of the marked effect of light dosage on egg production, all natural light was excluded, and replaced by artificial light adjusted to give similar exposure in all parts of the battery in so far as it was possible to judge by the use of an electric photometer. It should be understood that the group that received low animal protein during the growing period also received the lowest protein ration during this period of egg production and similarly for the other groups involved. The experiment as originally planned called for one-half of each group to be carried upon the same actual protein level as was used during the rearing period, and one-half to revert to the protein levels usually used during the egg production stage as a more accurate check upon the effect of the rearing treatment on subsequent production. This was found to be impractical, however, without reducing the number of birds per treatment to a dangerously low level in the statistical sense.

The rations fed were all-mash in nature and are shown in detail in Table 1. The ingredients of these rations, as originally made up, were adjusted to produce the analysis required as estimated from tables of analysis of feeds. When samples were chemically analysed, adjustments were made in the amount of corn starch to bring the analyses to the desired levels for all nutrients which were of principal concern. It will be noted that the protein levels actually fed were 12.5%, 14.5% and 16.5% for low, medium and high, respectively. All rations were adequate in riboflavin for egg production and this factor was increased to a level sufficient for hatchability before and during the period when eggs were being saved for hatching, by the addition of pure crystalline riboflavin. It should be pointed out also that the protein supplements (meat meal, fish meal, and buttermilk powder) varied proportionately from level to level thus further

TABLE 1.—INGREDIENTS AND CHEMICAL ANALYSES OF RATIONS USED

—	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
	%	%	%	%	%	%
Ground scratch grain	40	40	40	40	40	40
Ground oats	15	16	16	15	15	16
Wheat bran	7	7	7	7	7	7
Wheat shorts	6	6	7	6	6	7
Corn starch	20	16	12	18	14	8
Dehydrated alfalfa leaf meal	3	3	3	3	3	3
Buttermilk powder	1	2	3	2.5	2.5	2.5
Meat meal	1	2	3	—	—	—
Fish meal	1.5	3	4.5	—	—	—
Soy bean meal	—	—	—	2	6.5	10
Bone meal	2	1.5	1	3	2.5	3
Oyster shell	3	3	3	3	3	3
Salt (iodized)	0.25	0.25	0.25	0.25	0.25	0.25
Cod liver oil	0.25	0.25	0.25	0.25	0.25	0.25
Manganese sulphate (¼ lb. per ton)						
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Moisture	10.05	10.51	10.50	9.90	9.90	10.06
Protein	12.50	14.50	16.50	12.50	14.50	16.50
Fat (ether extract)	2.49	2.60	2.87	2.71	2.77	3.02
Ash	6.10	6.16	5.93	5.76	6.31	6.04
Fibre	4.90	4.15	4.23	4.32	4.82	4.67
Carbohydrates	63.96	62.08	59.97	64.81	61.70	59.71
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Calcium	2.23	2.32	2.08	2.02	2.17	2.17
Phosphorus	0.72	0.82	0.77	0.74	0.74	0.74

assuring that differences were due to level of protein uncomplicated by variation in the ratio of proteins of different characteristics such as amino acid constitution.

Complete substitution by soy bean meal for meat and fish meal was not attempted. An amount of 2.5% of the total ration or 0.85% of protein in each of the vegetable protein rations came from milk powder fed largely as a source of riboflavin but also because it is particularly efficient (1) as an amino acid supplement to soy bean meal. Throughout this paper the term vegetable protein will be used with reference to the rations whose supplementary protein is largely from a soy bean meal source the small amount of animal protein supplementation being understood.

The criteria used to assay the effects of the experimental treatments in this test were as follows: egg production (365-day and biological year) egg weight, weight of first 10 eggs, average body weight, maximum body weight, feed consumption and days to first egg, all on a per bird basis. In the case of the birds in the laying houses, feed consumption was available only for each pen. Egg weights were taken weekly throughout the test and body weight and feed consumption at 28-day periods. Both mortality and hatchability were also considered, the former on the basis of individual autopsy and the latter on the basis of the hatchability for each bird.

The data were subjected to exhaustive statistical analysis by the methods of variance and covariance and each criterion was adjusted for the effect of all pertinent correlated variables as follows: egg production adjusted for the effect of days to first egg, maximum body weight, average body weight and feed consumption; egg weight for days to first egg, weight of first 10 eggs, maximum body weight and feed consumption; weight of first 10 eggs for production, egg weight, maximum body weight and days to first egg; maximum body weight and average body weight for production, egg weight, feed consumption and days to first egg; feed consumption for egg weight, production, maximum body weight and average body weight. Correction was made to the adjusted means according to the technique elaborated by O'Neil and Gutteridge (7). In the case of feed consumption, which was not available on a per bird basis for the birds in the laying house, the variability determined for the birds in the laying battery was used. On analysis, no significant difference occurred between the replicate pens on the same treatment in the laying pens, an indication of satisfactory control of environment and that the data from these replicate pens could be combined for statistical analysis, which was done.

RESULTS

The data covering the 365-day period of the test are summarized in the following tables.

TABLE 2.—OBSERVED AND ADJUSTED MEAN VALUES FOR LOW, MEDIUM AND HIGH LEVELS OF PROTEIN†

—	Observed means			Adjusted means		
	Low	Medium	High	Low	Medium	High
	%	%	%	%	%	%
Egg production	150.2	178.0	185.5	159.6	178.1	176.5
Egg weight (gm.)	55.40	57.10	58.21*	55.44	57.09	58.16*
Weight of first ten eggs (gm.)	54.16	53.73	53.45	54.49	53.83*	52.96
Average body weight (lb.)	5.37	5.94	6.05	5.24	6.05	6.07
Maximum body weight (lb.)	6.14	6.58	6.67	6.26	6.62	6.51
Feed consumption (gm./day)	118.3	122.3*	127.8	127.6	119.4	121.4
Days to first egg	240.6	227.7	219.4*	237.8	228.4	221.4*

* Significantly superior values when compared at $p = 0.05$ between high and medium protein levels.
† Number of birds—low 122; medium 128; high 116.

Actual differences and necessary differences are not quoted for the sake of brevity. Between medium and low, and high and low protein levels all differences are significant for all criteria, and, with the exception of feed consumption and weight of first 10 eggs, favourable to the higher levels of protein. As well as being significant the differences are sufficiently great to be of some practical importance, and on the basis of these data a level of protein as low as was used in this test, namely, 12.5%, is too low for purposes of egg production.

Between high and medium levels of protein differences are smaller. The difference of 7.5 eggs in observed production is not significant and therefore may be due to chance rather than to the level of protein. Egg

weight and days to first egg significantly favour the high protein level but by differences of only 2% and 3.7%, respectively. Feed consumption was lower on the medium protein level. Considering the adjusted means, in which allowance has been made for the effect of days to first egg, maximum body weight, average body weight and feed consumption upon egg production it is seen that no direct effect of protein level on egg production *per se* has been brought about, the observed difference being due to the influence of these characters which could not be controlled but could be and were measured, rather than to rate or persistency or other factors which go to make up the complex, egg production. Since the rearing treatment had a definite effect upon days to first egg (5) the adjustment for these factors is particularly necessary if a comparison of these groups on the basis of egg production is to be unbiased. High protein did have a direct favourable effect upon egg weight and days to first egg as was the case also with the observed means although the actual differences were small. The lower level of protein was slightly more favourable to large egg size in the first 10 eggs. On the basis of the same egg weight, body weight and egg production, feed consumption of the medium protein group was almost identical with that of the high protein group thus giving at least equal efficiency in use of feed. No effect of medium as opposed to high protein level either direct (adjusted means) or indirect (observed means) upon average or maximum body weight was found in these data.

The results of the comparison of animal and vegetable protein sources are show in Table 3.

TABLE 3.—OBSERVED AND ADJUSTED MEAN VALUES FOR ANIMAL AND VEGETABLE PROTEIN SOURCES†

—	Observed means		Adjusted means	
	Animal protein	Vegetable protein	Animal protein	Vegetable protein
Egg production	174.2	167.5	172.7	169.4
Egg weight (gm.)	56.97	56.82	57.43*	56.26
Weight of first ten eggs (gm.)	53.12	54.57*	53.19	54.44*
Average body weight (lb.)	5.79	5.78	5.86*	5.69
Maximum body weight (lb.)	6.46	6.46	6.50	6.41
Feed consumption (gm./day)	121.9	123.8	121.4*	124.5
Days to first egg	224.7*	234.7	224.6*	234.5

* Significantly superior values when compared at $p = 0.05$.
† Number of birds—vegetable protein 164; animal protein 202.

No significant difference occurred (observed means) between animal and vegetable protein groups excepting in weight of first 10 eggs and days to first egg. That the weight of the first 10 eggs should be higher for the slower maturing group is reasonable in view of a correlation of + 0.5 between these characters in these data.

The adjusted means indicate that the apparent difference in production in favour of the animal protein group is probably due to correlated factors such as days to first egg and feed consumption, as indicated by a large reduction in the difference when allowance is made for these factors, rather

than to a direct effect of source of protein upon production. Animal protein was favourable to maintenance of a high average body weight and egg weight, to a more efficient use of feed for production, maintenance and egg size, and to more rapid sexual maturity. The last mentioned difference of 10 days in sexual maturity is the difference of greatest practical importance and this might be considered therefore to be the most potent effect of animal protein in this test.

Table 4 shows the pertinent data for the birds kept in laying batteries and in laying houses.

TABLE 4.—OBSERVED AND ADJUSTED MEAN VALUES FOR PULLETS KEPT IN BATTERIES AND IN LAYING PENS†

—	Observed means		Adjusted means	
	Battery	Laying pens	Battery	Laying pens
Egg production	184.1*	157.7	188.2*	153.7
Egg weight (gm.)	57.01	56.77	58.5*	55.2
Weight of first ten eggs (gm.)	51.74	55.94*	52.2	55.4*
Average body weight (lb.)	5.99*	5.57	6.45*	5.08
Maximum body weight (lb.)	6.65*	6.27	6.95*	5.94
Feed consumption (gm./day)	115.0*	131.1	111.1*	135.4
Days to first egg	220.1*	238.9	221.5*	237.5

* Significant differences at $p = 0.05$.
† Number of pullets—battery 187; laying pens 179.

A difference of 26 eggs in favour of the battery method of housing of laying pullets proved to be a real effect of the environment of the laying cage when it became a difference of 34 eggs per bird after making allowance for the effect of the other pertinent uncontrolled variables. In every criterion excepting weight of first 10 eggs, the battery gave superior results, and this exception may be explained by the relationship between this character and days to first egg previously noted. The differences are, for the most part, of high magnitude and represent an effect of practical importance. A point of considerable importance is the fact that the additional egg material was produced, and the higher body weight built up and maintained on a much lower feed consumption for the birds in the battery. These effects were due, without doubt, to the saving of feed brought about by the supplying of heat to a moderate temperature in the battery room, thus lowering the feed requirement for maintenance of body temperature and by the enforced inactivity of the birds in the cages with its concomitant saving of feed for energy production.

Biological Year Production

In view of the fact that the pullets used in this experiment were relatively late hatched, the possibility existed that the most retarded groups, when their production for 365 days from the time of entering the laying house was used, would be discriminated against in that their production might persist longer into the early winter and that they might eventually make as high production as some of the groups whose [illegible] of

first egg was much earlier. Production was therefore recorded for all the birds in the battery until they went into the moult which did not occur in some instances until the end of January or 15 months from the beginning of the test. The average production of all groups was some 10 to 15% higher on this basis, but the relation between production on the three protein levels and the two protein sources was essentially the same as for the period covered by the data already reported. It is of interest to note that rate of production, i.e., number of eggs laid during the biological laying year divided by the number of days from first to last egg, did not differ significantly for animal and vegetable protein nor for medium and high protein levels but did so significantly for medium and high protein levels over low level.

Hatchability

As previously stated all rations fed in this test contained sufficient riboflavin to meet requirements for production and hatchability. After the data from those individuals which had given no fertility were eliminated from consideration the remaining data were expressed as degrees of an angle (3) preparatory to statistical analysis. No differences between protein levels were significant and the actual hatchability of fertile eggs was as follows: low protein 77.9%, medium protein 73.5% and high protein 75.1%; animal protein 78.5%, vegetable protein 71.7%. It seems obvious that level of protein had no effect on hatchability, but that the animal source did give significantly superior results to the vegetable, by 6.8% in this instance.

Mortality

Mortality and cause, as determined by autopsy, were tabulated. No trend of any kind was exhibited in so far as cause is concerned. As to level of mortality the figures were: battery 18.6%, laying pens 19.5%; animal protein 17.5%, vegetable protein 18.9%; low protein 17.4%, medium protein 13.3%, high protein 23.3%. When the month to month mortality was compared statistically by the binomial method the mortality of the high protein group proved to be significantly greater than that of the medium and low protein groups. All other differences were non-significant. It would seem therefore that the highest protein level was a greater predisposing factor to mortality than any other of the protein levels under experiment.

Cost of Production

The adjusted means for feed consumption, shown in Tables 2, 3 and 4, are admirably suited for use as a basis for comparison of cost of production since they represent the feed used by each group to produce the same number and size of eggs and maintain the same body weight. On this basis for the year's production, the medium level of protein was more economical than the low and high levels by 6 cents and 13 cents per bird, respectively; the animal than the vegetable protein by 4 cents; and the battery than the laying pen by 35 cents per bird. These figures represent feed costs only.

DISCUSSION

Level of Protein

Barred Rock pullets when reared on a low protein ration (average protein 12.5%) and subsequently carried through a laying year on a similar ration containing the same level of protein, failed to give satisfactory results as judged by the following criteria: egg production, egg weight, body weight, and days to first egg. Suitable statistical treatment of the data showed that to a moderate degree the low production obtained was due to delayed sexual maturity, as when allowance was made for the effect of this factor the production was somewhat increased. Even after such adjustments were made, however, the average production per bird was still some 17 eggs lower than the next highest protein level, hence it is obvious that as low a level as 12.5% of protein in the laying ration has a direct retarding effect upon egg production. Since the lower level of protein feeding during both the rearing and production periods must be considered to be responsible for the retarded sexual maturity, the lower production of 28 eggs per bird must be debited to the lower level of protein feeding.

Between medium and high protein levels differences are not great. Setting aside the effect of days to first egg, which is largely a result of rearing treatment, no direct difference in effect of high or medium level of protein was measurable and it may be stated that the high level of protein used in this test during the period of egg production did not affect the rate of production of eggs. It did, however, favourably affect the size of the egg in spite of the tendency for the more rapid sexual maturity induced by a high protein level to produce a lower weight of the first eggs laid.

Considering the total period of the experiment from hatch to the end of the laying period, the most striking effect of variation in protein level is that upon sexual maturity (days to first egg). The lowest protein level seriously retarded sexual maturity and the medium level significantly so, although by only 8 days as against 21 days in the case of the lowest level.

Cost per unit of production is the final criterion in determining the usefulness of any treatment and on the basis of equal performance in production, egg size and body weight a saving of 13c. per bird per year in economy in feed cost was made in using the moderate level (14.5%) of protein rather than the high level (16.5%), whereas a saving of only 6c. per bird was made by the use of the low level (12.5%).

Source of Protein

Animal protein was significantly superior to vegetable protein in body weight and feed consumption and in rate of sexual maturity, which, as previously noted, is largely traceable to the effect of vegetable protein in the rearing phase. Egg weight and weight of first 10 eggs favoured the vegetable protein source. Under the circumstances it would seem that substitution of vegetable protein (soy bean meal) for the animal protein supplements was more satisfactory for egg production than for rearing of pullets (5). It is reasonable to believe, in view of published information with regard to protein levels in rearing, that this period is somewhat more exacting than the period of egg production from the standpoint of source of

protein, possibly because of greater requirements for specific amino acids for growth as against maintenance and production of eggs. Hatchability was also superior for the birds on animal protein.

Battery vs. Laying House

With one exception all criteria indicate the superiority of the laying battery as opposed to the laying pen. The one exception, weight of first 10 eggs, represents a very large difference in egg weight which tentatively must be explained by slower maturity in the laying pens, with probable greater body weight at date of first egg as against a depressing effect upon early egg size in the battery brought about by the reverse of the above conditions. The high positive correlation of body weight on egg weight and of days to first egg on weight of first 10 eggs suggests that as a possible explanation. This is not borne out, however, by the adjusted means in which allowance is made for the effect of the factors mentioned. Actually, the elevating effect of late sexual maturity upon weight of first 10 eggs in the case of the laying pen was counteracted by an early high rate of production in the laying battery, indicating that the large difference still existing after adjustment was a direct effect of the environment of the laying cage. That this early advantage of the laying pen did not persist is evidenced by the significantly and considerably higher egg size in the battery on the average over the whole period of the test. Although starting on equal terms, the environment of the laying cage was responsible for the production of many more and larger eggs, a larger body weight and a much more rapid sexual maturity, all this accomplished on a very much lower feed consumption. The last mentioned factor was of course, due to the decreased requirement for feed to support activity and body temperature in the restricted space of the laying cage and the partially heated air of the battery room. In terms of economy of efficiency of production, 18% less feed, valued at 35 cents per bird, was required to make the same production, egg size and body weight. When the market value of the additional production is considered the laying battery proves to be very much superior to the laying pen.

It should be realized that the favourable effect of the battery environment would not necessarily be evidenced to so great a degree if early hatched pullets, already mostly sexually mature, were being used. For moderately late hatched birds (May 15) under climatic conditions similar to those of this area, a decided improvement in production, egg weight and body weight may be expected.

SUMMARY

Barred Rock pullets which had been reared on low (12.5%), medium (14.5%) or high (17.0%) protein levels, of which the supplementary protein came from either animal or largely vegetable sources, were continued during the period of egg production on low (12.5%), medium (14.5%) or high (16.5%) protein levels. These birds were equally divided between laying batteries and laying houses. The following information was derived from these tests.

(1) A level of 12.5% of protein was too low for satisfactory production of eggs. This group was inferior in egg production, egg weight, average body weight, days to first egg, and feed consumption to those on each of the higher levels of protein.

(2) A level of 16.5% of protein was superior to one of 14.5% only in egg size and days to first egg. Feed efficiency was greater for the group receiving 14.5% protein, and production at this level was the most economical of that at any level.

(3) Animal protein supplements gave superior results to vegetable protein even though the latter was supplemented by 2.5% of powdered buttermilk. The differences were small, however, except in the case of sexual maturity as measured by days to first egg, in which a difference of 10 days was recorded in favour of the animal protein mixture. In economy of production and in hatchability the animal protein supplement was also superior to a moderate degree.

(4) Pullets which were kept in the cages of a laying battery were very much superior in all respects to those which were kept in laying pens. The degree of superiority is evidenced by the difference of approximately 26 eggs per bird. As the pullets used were moderately late hatched for the area (May 15) it does not follow that so great a difference should necessarily be expected with early hatched birds which would normally be in production before the onset of very cold weather.

(5) Mortality was similar for all treatments with the exception of the high protein level where a death rate significantly higher than that of the medium and low protein groups was experienced.

On the basis of the results reported herein and of those of the rearing phase of this experiment previously reported, it is concluded that a very low protein level, viz., 12.5% is too low for satisfactory rearing of pullets and for subsequent egg production. A level of 14.5% of protein, on the other hand, may be expected to give very similar growth, and greater efficiency in rearing at a lower cost than a level of 17%, and equally as satisfactory results as those from a 16.5% level during the period of egg production following.

Also, for both growth and egg production, a mixture of the common animal protein supplements—fish meal, meat meal and buttermilk powder—may be expected to give superior results to one made up of soy bean meal with a small percentage (2.5%) of buttermilk powder. Since the superiority of the former is consistent but relatively small in actual degree, the use of the latter is indicated in times of scarcity or when price levels favour the vegetable protein source to a marked degree.

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ERRATUM

In the December 1943 issue of *Scientific Agriculture* (Vol. 24, No. 4), the Book Review "The Parasite Catalogue of The Imperial Parasite Service," Page 199, Part 1, should read:—

Part 1, listing about 1,000 species of Arachnida and Coleoptera and about 1,300 species of parasites (pp. ix and 151) and Part 2, listing about 600 species of Dermaptera and Diptera, are now ready.

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ASSOCIATION OF CHARACTERS IN PETUNIA

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Because of its popularity as a garden flower, and the many forms on the market, one would expect more to be known and published about the inheritance of characters in the petunia (*Petunia violacea* and *P. axillaris* and their derivatives).

A review of literature (1) shows that the inheritance of flower colours in petunia is as follows:

Violet is dominant over red, and over lilac on a monogenic basis;
Violet red is dominant over white with the F_1 colour intermediate;
Uniform flower colour is dominant over flower colour with green margins;
For other flower colours a more complex inheritance is reported.

Inheritance of flower type has been determined (1), namely:

Single × single gives all singles, single × double gives a 1 : 1 ratio, and double × double gives about 3 doubles to 1 single in F_2.

In the inheritance of pollen colour in garden petunia four pairs of genes are involved (1).

Self-fertility in petunia has been considered to vary in degree. It has been shown that pollen tube growth is arrested in stylar tissue (2). From crosses made in the process of carrying out the studies presently reported the writer believes that much self-sterility thought to exist in petunia may be overcome by practising bud pollination. In fact, seldom were bud pollinations a failure in crosses involving the Flaming Velvet, Hollywood Star, and California Giant varieties of petunia.

Self-sterility was interpreted on the basis of four multiple allels by Harland and Atteck (3). When these workers selfed by bud pollination four normally self-sterile lines they obtained from the four lines:

One line which was dwarfed, one homozygous lethal line, and two lines normal in appearance.

Levan (4) has shown that sterility is influenced by chromosome number and complement, trisomic plants being more sterile than diploid plants. Levan also states, "Self-pollination certainly takes places frequently even in free flowering (open pollination) as the stamens in petunia dehisce already in the bud stage, and early pollination has always proven to give the best results" (p. 108 l.c.).

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EXPERIMENTAL

In 1940 a petunia breeding project was undertaken with a view to determining the mode of inheritance of certain plant characters of the petunia varieties Flaming Velvet (F.V.) and Hollywood Star (H.S.). The characters of these varieties with which the study is concerned are detailed in Table 1.

TABLE 1.—CHARACTERS OF PETUNIA VARIETIES

Character	Flaming Velvet	Hollywood Star
Plant	Vigorous, free-flowering, moderately large.	Of medium vigour, very free flowering, moderately small.
Leaf type	Normal	Wilty (might be called wiry).
Mature leaf index (Length: width ratio)	Low	Medium high.
Flower size	Medium large	Medium small.
Flower colour	Deep violet	Rose pink.
Corolla segments	Sinuses shallow, broadly pointed.	Sinuses deep, sharply pointed

Plants of parental varieties were grown to maturity in plant pots in the greenhouse at The University of Manitoba, Winnipeg. Hollywood Star was used as the pollen parent, and from crosses made, Flaming Velvet as seed parent, the first hybrid seed was harvested August 16, 1940. This hybrid seed was sown October 1, 1940, and the first hybrid plants bloomed February 25, 1941. The appearance of an F_1 plant in comparison with a Hollywood Star plant may be noted from Figure 1.

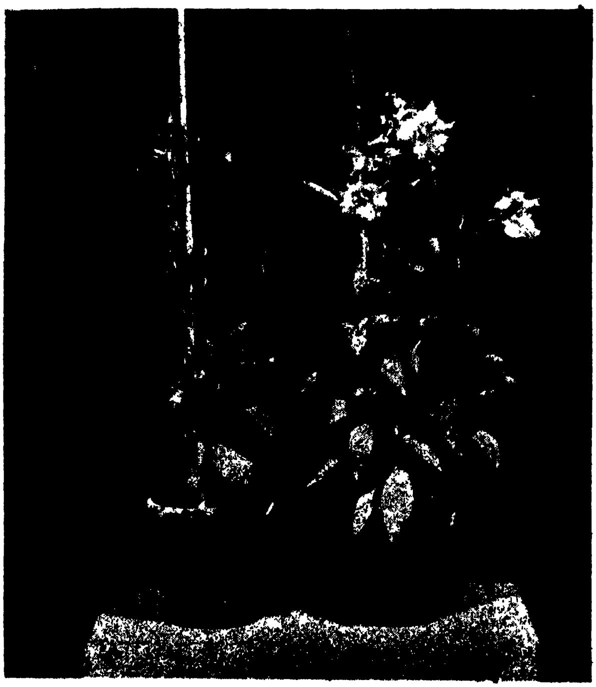

FIGURE 1. F_1 hybrid petunia plant (F.V. × H.S.) left. H.S. parent plant right.

It should be noted that the F_1 hybrid plant manifests none of the Hollywood Star characters previously described, having broader leaves, and producing flowers darker in colour, fewer in number and less deeply lobed. In other words it closely resembles the Flaming Velvet parent except that the flower colour is intermediate. As a bedding petunia it is very attractive.

Flower outlines of Hollywood Star and the F_1 hybrid are shown in Figure 2, so that a clear picture of the two flower forms might be obtained.

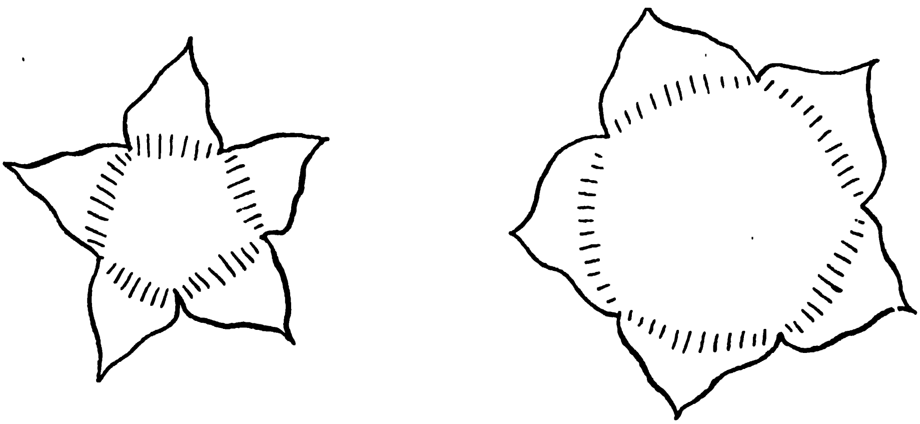

FIGURE 2. Hollywood Star (left); F_1 Hybrid (right) (natural size).

From mature Hollywood Star and F_1 hybrid plants dimensions of leaves and calyx lobes (presented in Table 2) were obtained. The average measurements given represent 48 determinations for each character.

TABLE 2.—AVERAGE LEAF AND CALYX LOBE DIMENSIONS OF HOLLYWOOD STAR AND F_1 HYBRID PETUNIAS 1941

Character		Hollywood Star	F_1 Hybrid (F.V. and H.S.)
Leaf	Length (mm.)	74.54	61.46
	Width (mm.)	21.90	28.48
	Length: Width (Index)	3.40	2.16
Calyx lobe	Length (mm.)	16.56	15.58
	Width (mm.)	1.83	2.56
	Length: Width (Index)	9.05	6.09

No attempt was made to obtain flower or corolla dimensions. That differences exist between leaves and calyx lobes of the H.S. parent and F_1 hybrid (F.V. $\times$ H.S.), the measurements given in Table 2 plainly show.

Some F_1 hybrid plants were allowed to self and produce seeds, but other plants were backcrossed with the H.S. recessive parent. In all controlled cross- and self-pollinations bud pollination was practised. This invariably resulted in early development of a high seed content in each seed capsule. From time of bud pollination to mature seed development in the petunias studied not more than 5 weeks elapsed.

To permit a preliminary study to be made of segregation in F_2 of characters considered in this cross, seeds from selfed F_1 plants were sown in The University of Manitoba greenhouse April 14, 1941. The seedlings were transplanted and grown to flowering stage in the usual procedure of handling flowering plant seedlings. Two progenies were carried to maturity and notes were taken as to plant types and flower forms of F_2 plants.

As will be realized, one seed capsule may contain many hundreds of seeds. When these seeds are sown under conditions favouring germination, no matter how favourable the environment, it is practically impossible to carry to maturity all of any one progeny; damping-off may destroy some plants, insects may further reduce the number, and through general and genetic weakness others may die prematurely.

RESULTS

The number of F_2 seedlings having F.V. and H.S. types of leaf were 126 and 12, respectively, giving a ratio of 10.5 : 1. This is not in good agreement with either the 3 : 1 or the 15 : 1 theoretical ratio. However, the plants with the H.S. type of leaf were on the average, of weaker constitution than the other types. As the germination of seeds sown and survival of seedlings were not complete it is probable that the embryos with the genotype for the H.S. leaf type survived in lower proportion than the others. If correction for this condition were possible it would modify the obtained ratio in the direction of a 3 : 1 ratio.

As will be seen from the following tables a number of the F_2 plants failed to bloom when data on blossoming were secured.

Tables 3, 4 and 5 show the results obtained when F_2 plants were classified for flower colour, leaf type, and corolla form.

TABLE 3.—CLASSIFICATION OF PLANTS AS TO FLOWER COLOUR IN TWO F_2 PROGENIES, 1941

Progeny	Colour of dark coloured parent (F.V.)	Intermediate in colour like F_1*	Colour of light coloured parent (H.S.)	Total
1	12	29	15	56
2	18	29	17	64
Observed	30	58	32	120
Theoretical (1 : 2 : 1 basis)	30	60	30	

* Flower colour of F_1 plants was intermediate between flower colours of parents; this finding is in agreement with results previously referred to during a review of literature (1).

Results in Table 3 indicate a monogenic basis for inheritance of flower colour, and this character did not seem to be associated with differential vigour of F_2 plants.

Tables 4 and 5 are presented in 2 × 2 form in order to show if association existed between the characters being studied. The data necessarily only included plants which bloomed.

TABLE 4.—FREQUENCIES OF F_2 PLANTS HAVING DIFFERENT LEAF TYPES AND COROLLA FORMS

		Leaf type		Total
		F.V. and Intermediate	H.S.	
Corolla Form	F.V. and Inter.	113	0	113
	H.S.	0	7	7
Total		113	7	120

P for independence = extremely small.
* Calculated by the direct probability method for 2 × 2 tables (5).

The data in Table 4 indicate a complete association between the leaf types and corolla forms studied. The *P* value shows that if these characters were inherited independently the probability of obtaining a distribution such as that actually obtained would be extremely small.

It will be noted that only seven plants (58%) of the original 12 H.S. type bloomed, whereas in the F.V. and intermediate class 113 (90%) of the original 126 bloomed. The weak constitution of H.S. type plants is believed to account for the low percentage which bloomed. These data are therefore not considered reliable as a basis for determining the factorial basis of inheritance of leaf type and corolla form. The close fit of the 113 : 7 distribution to a 15 : 1 ratio is considered to be coincidental.

TABLE 5.—FREQUENCIES OF F_2 PLANTS HAVING DIFFERENT LEAF TYPES, COROLLA FORMS AND FLOWER COLOURS

		Leaf type and corolla form		Total
		F.V. and Intermediate	H.S.	
Flower colour	F.V. and Inter.	81	7	88
	H.S.	32	0	32
Total		113	7	120

P for independence = 0.2134

In Table 5 the *P* value indicates that flower colour is inherited independently of leaf type and corolla form. The typical monogenic inheritance of flower colour has already been mentioned. The frequencies of plants in this table (81, 32, 7.0) are very similar to the theoretical frequencies based on a bifactorial inheritance of leaf type and corolla form, namely, 84.4, 28.1, 5.6, 1.0. But, as pointed out above, this is regarded as coincidental and conditioned by a heavy disproportionate loss of the H.S. type of plant.

BACKCROSS POPULATIONS

From the back crosses made in 1941 progenies from 4 seed capsules were developed in 1942 at The Forest Nursery Station, Indian Head, Sask.

The seeds were sown, and the seedlings handled under conditions whereby practically all seeds germinated, and losses of seedlings were kept at a minimum.

When the seedlings were being transplanted into flats from the seed pans, and later into the garden, no attempt was made to separate the individual seedlings. By setting out groups of 3 or more seedlings roots were disturbed very little, and large populations were handled with a minimum of care.

At maturity and when in full bloom the groups of plants were pulled, and the individual plants examined as to leaf type and flower form. Two classes were adapted for each character, as the so-called "intermediate types" resembled the F.V. type too closely to be given a separate classification.

TABLE 6.—FREQUENCIES OF BACKCROSS PLANTS HAVING DIFFERENT LEAF TYPES AND COROLLA FORMS (TOTAL OF 4 PROGENIES)

		Leaf type		Total
		F.V. and Intermediate	H.S.	
Corolla form	F.V. and Inter.	224	0	224
	H.S.	0	159	159
Total		224	159	383

P for independence = extremely small.

The backcross data in Table 6, like the F_2 data, show no crossovers between leaf type and corolla form. The association of these characters appears to be complete. The ratio of the frequencies of the two types is rather unbalanced for a backcross F_1 population. This is no doubt due to failure of a portion of the H.S. types to survive or to bloom. These were, on the average, as in F_2 progenies, less vigorous than F.V. types.

Any correction for this condition would make the obtained ratio approach 1 : 1 more closely. The actual data in Table 6 do not fit this theoretical ratio well as the χ^2 and P values for this fit are 11.03 and 0.01 respectively.

CONCLUSIONS

In the petunia cross Flaming Velvet × Hollywood Star, violet (F.V.) flower colour is partially dominant over pink (H.S.) and is inherited on a monogenic basis. The F_1 flower colour is intermediate between the parental flower colours.

Leaf type and corolla form of Flaming Velvet are dominant over the corresponding characters of Hollywood Star.

The factor or factors determining leaf type and corolla form studied appear to be either strongly linked or identical.

The factorial basis of inheritance of the leaf type and corolla form studied cannot be determined with a high degree of probability on the basis of the present data. Monogenic inheritance, however, appears to be the most likely in each case.

SUMMARY

The petunia variety Flaming Velvet which has broad leaves, violet flowers and broadly pointed corolla lobes with shallow sinuses was crossed with the variety Hollywood Star which has narrow leaves, rose pink flowers and sharply pointed corolla lobes with deep sinuses.

F_1 and F_2 populations as well as F_1 backcross populations of (F.V. × H.S.) × H.S. were examined with respect to the characters studied. Flaming Velvet type was in every case dominant, the dominance being only partial in the case of flower colour.

Flower colour appeared to be inherited on a monogenic basis, and independently of both leaf type and corolla form.

Leaf type and corolla form appear to be determined by factors which are closely linked or identical since no crossovers were obtained in the F_2 or backcross populations.

Plants with the Hollywood Star leaf type and corolla form were, on the average, of weaker constitution than other plants. This condition made a factorial analysis of inheritance unreliable. A monogenic basis for leaf type and for corolla form appears most probable.

FIGURE 3. Plants from same seed capsule F.V. type (left). H.S. type (right).

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STUDIES ON CROWN AND ROYAL FLAX IN FLAX-SICK SOIL

I. THE DETERMINATION OF CROWN AND ROYAL SEED SAMPLES BY GROWTH IN FLAX-SICK SOIL[1]

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Royal flax is a variety resistant to wilt (*Fusarium Lini* Bolley) under Saskatchewan conditions. It was developed by Dr. J. B. Harrington at the University of Saskatchewan as a selection from the wilt-susceptible variety Crown in the old wilt nursery (on block 505 of Bracken Field) during the period 1926 to 1941. It also shows a high resistance to rust (*Melampsora Lini* (Ehrenb.) Desm.) compared with Bison and Redwing, the two other varieties commonly grown in the province. The seed of Crown and Royal is medium in size and generally brown in colour, fading to pale yellow at the distal or wider end. It is consequently not possible to determine visually the exact identity of an unknown sample of these varieties. Primarily as a result of the flax-rust epiphytotic in 1942 and because of the need for increased flax production as a war-time measure, University and Government authorities recommended that Royal should replace Bison and Crown in the southern and central flax-growing areas of Saskatchewan, but that Redwing should still be grown in the northern park zone.

The replacement of Bison and Crown by Royal, for various reasons, must take several years. Its fulfilment was retarded by the limited supply of Royal seed from the 1942 crop, but with the increase in acreage of Royal in 1943, ample supplies should be available in the future.

In the late fall of 1942 growers began submitting flax-seed samples to the University of Saskatchewan and to the Dominion Seed Laboratory, Plant Products Division, Saskatoon, requesting variety determinations. The small brown seed of Redwing and the moderately large brown seed of Bison could readily be identified by seed analysts, but, as indicated above, the separation of Crown and Royal seed presented a problem. This separation could readily be secured by growing the unknown samples in the wilt nursery during the following summer, but to be of most help to the growers the information would have to be available before the spring sowing. Fortunately about 3 buckets of flax-sick soil had been collected from the new wilt nursery (on block 1203 of Bracken Field) before freeze-up in connection with flax-disease studies. Preliminary trials with known samples of Crown and Royal in this soil in the greenhouse gave severe wilt in Crown (82 to 92% in 5 small-scale tests), and a trace of wilt in Royal (0 to 3%). On the basis of these results routine tests were made in the greenhouse on 96 flax-seed samples of undetermined Crown and Royal, with the University strains of Crown and Royal as controls. The farm samples originated from country points in which all the major flax-growing

[1] Co-operative investigation between the Laboratory of Plant Pathology, University of Saskatchewan, and the Dominion Seed Laboratory, Plant Products Division, Saskatoon. Financial assistance to the University Laboratory was furnished by the Saskatchewan Agricultural Research Foundation.

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areas of the province are represented. To test the reliability of the greenhouse method, 68 out of the 96 samples were tested for their reaction to blight and wilt in the new wilt nursery during the summer of 1943. The varietal identities of the 28 samples not included in the field test were quite definite; 11 of them determined as Royal gave 0.55% wilt in the greenhouse test, while 17 determined as Crown gave 93.0% wilt. Much of this testing was conducted in co-operation with Mr. T. W. L. Burke, Supervisor of the Dominion Seed Laboratory, Plant Products Division, Saskatoon, who supplied 87 seed samples and much of the help in seed sowing and the various counting operations.

These experiments were undertaken in an attempt to obtain a relatively quick and reliable means of settling the identity of doubtful Crown and Royal seed stocks or of indicating possible admixtures of these two varieties. The methods used and the results obtained in both the greenhouse and the field are presented in this paper. Until such a time as Crown has been entirely replaced by Royal in Saskatchewan, the greenhouse method may be of value to others who might find the need of making similar tests.

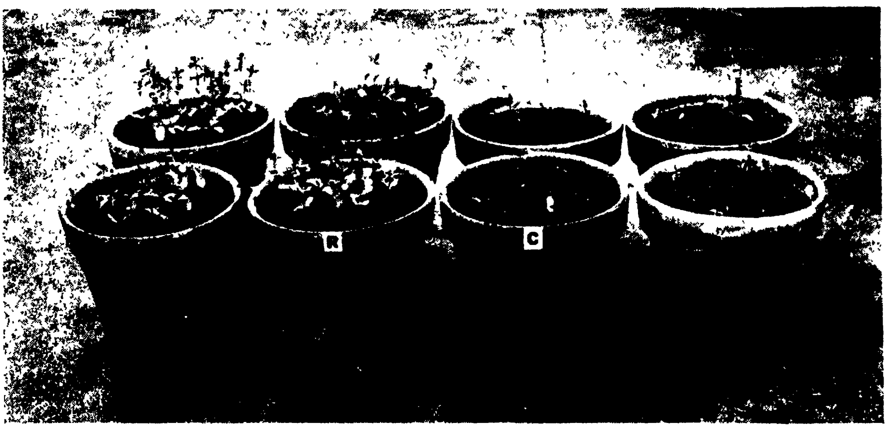

FIGURE 1. The identification of undetermined seed samples of Crown and Royal flax in flax-sick soil. R, Royal control; the other three pots at the left have been determined as Royal. C, Crown control; the other three pots at the right have been determined as Crown.

MATERIALS AND METHODS

The flax-sick soil used in the greenhouse experiments came from the new wilt nursery in which the field experiments were also conducted. This nursery (on block 1203) was started in the spring of 1940 by distributing flax-sick soil from the old nursery (on block 505) lightly over the surface and working it in. It was then sown to wilt-susceptible Crown during the three years 1940 to 1942 inclusive. In this last year more than 90% of the plants succumbed to wilt.

In the preliminary greenhouse experiments the undetermined Crown and Royal flax samples, with the University strains of these varieties as controls, were sown in the flax-sick soil in 6-inch pots with 25 seeds of each sample per pot (Figure 1). All subsequent experiments were conducted in large shallow flats 34 by 28 by 3 inches deep. Because of the limited

supply of soil 3 tests had to be run at different times, with each test having its own controls. Thus the greenhouse figures in Table 1 represent the averages of 3 tests for the controls and 1 test for each numbered sample. Fifty seeds of each sample were sown ½ inch deep and ½ inch apart in rows 1½ inches apart. Total germination counts were made when seedling blight began to show up in the Crown control; this was usually about 12 to 14 days after sowing, but varied with the temperature conditions. In another 12 to 14 days, or longer depending on the temperature, the seedling survivors were counted and the number of wilted seedlings per row was obtained by difference. The experiment was observed a few days longer

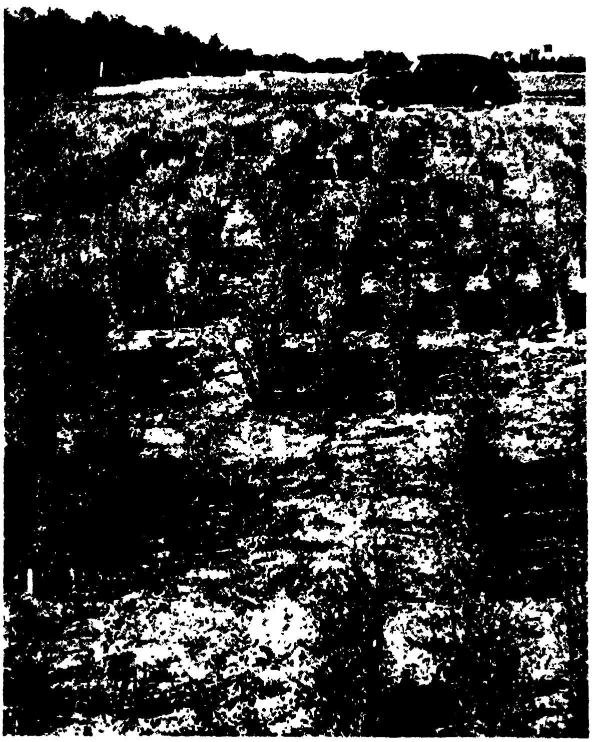

FIGURE 2. The section of the new wilt nursery in which the undetermined samples of Crown and Royal were grown. From visual examination alone it is easy to detect which of the four-foot rows are Crown samples (73 to 100% wilt), and which are Royal (less than 30% wilt).

and doubtful samples were given a second survival count. The percentage of wilt is based on the number of seedlings which emerged and not on the number of seeds sown. The same method of calculation was used with the field results. Samples in which the variety was not definitely indicated in the first test, or which might be mixtures of the two varieties, were given a second test. Varietal identity was determined primarily by comparing the percentage of wilt with those of the controls, but consideration was also given to the vigour of the surviving plants. In general, the survivors in the control rows of Crown were less vigorous than those in the control

rows of Royal. At the completion of the experiment the seedlings were hand pulled and as many of the fine roots as possible were removed from the soil with a home-made wire cultivator. The flax-sick soil was then diluted one-seventh with ordinary field soil, rested for 1 week and again sown to flax. The dilution did not appear to reduce the potency of the flax-sick soil, which had apparently reached its maximum. In this way the limited supply of soil was gradually increased.

The field test was conducted on 53 samples in the new wilt nursery (Figure 2) from which the soil used in the greenhouse tests was obtained the previous fall, and on 15 samples in an area of lightly infested soil adjoining this nursery. Varietal field determinations on these 15 samples were based on visual examination only. Each sample was sown in 2 randomized 4-foot rows with 200 seeds to each row. All rows were 8 inches apart. Total emergence counts were made on the 53 samples 21 days after sowing, and survival counts 33 days later. Calculations and varietal determinations were carried out as already described for the greenhouse tests.

EXPERIMENTS AND RESULTS

It should be emphasized that in these tests "percentage wilt" represents the percentage of post-emergence mortality of seedlings regardless of the causal organism involved, and not to *Fusarium Lini* alone. Thus isolations from diseased and dead seedlings have yielded *Rhizoctonia Solani* Kühn (*Pellicularia filamentosa* (Pat.) Rogers), *Pythium de Baryanum* Hesse and, to a lesser extent, *Fusarium* spp., in addition to *Fusarium Lini*.

The quantitative results of the comparative greenhouse and field tests of 53 seed samples together with the variety indicated are given in Table 1.

Samples Deserving Special Comment (See Table 1 on opposite page).

927—In its first greenhouse test this sample was recorded as indefinite, but in the repeat test it was considered to be Crown in spite of the moderate percentage of wilt (56%) as all the survivors were sickly. The field results supported this latter determination (100% wilt).

1310—This sample was recorded as "Royal?" (21% wilt) in its first greenhouse test. A second test gave 75% wilt; a third test was then made: this gave 77% wilt. In all of these tests the survivors were vigorous. The sample was determined as predominantly Crown, with probably an admixture of Royal. The field results indicated Crown (84% wilt).

1532—The first greenhouse test was indefinite (50% wilt), but the repeat test clearly indicated Crown (84% wilt). This result was borne out by the field test (99% wilt).

1982 and 1984—Two greenhouse tests indicated that these samples were mixtures of the two varieties (averages of 47 and 58% wilt, respectively). In both, the survivors were vigorous. The field determinations were recorded as Crown (63 and 69% wilt, respectively), but it would seem that these percentages of wilt in the field do indicate a probable admixture of Royal, so that even in these two cases the greenhouse and field results are in accord.

2523—Two greenhouse tests averaged 26% wilt, with surviving plants vigorous. This indicated Royal with probably a slight admixture of Crown. The field inference was "Royal?" (33% wilt). The greenhouse determination is probably correct.

TABLE 1.—COMPARATIVE RESPONSE OF UNDETERMINED CROWN AND ROYAL SEED SAMPLES IN FLAX-SICK SOIL IN THE GREENHOUSE AND THE FIELD

Sample No.	Emergence		Wilt*		Variety indicated
	Greenhouse	Field	Greenhouse	Field	
	%	%	%	%	
Crown	98	78	87	99	
Royal	100	73	1	25	
565	80	68	75	89	C†
595	28	36	85	100	C
640	44	72	0	18	R†
641	52	62	77	100	C
701	52	67	7	17	R
703	60	67	13	22	R
751	60	73	73	100	C
927‡	100	83	56 (56)§	100	C
1008	60	72	7	19	R
1108	52	67	85	97	C
1306	56	56	85	82	C
1307	52	75	77	92	C
1309	60	79	13	24	R
1310‡	57	60	21 (76)	84	C
1312	96	84	17	16	R
1327	56	50	14	12	R
1388	80	87	70	100	C
1390	84	75	86	87	C
1397	76	82	84	90	C
1468	45	65	20	26	R
1532‡	43	56	50 (84)	99	C
1580	80	75	10	34	R
1656	30	62	86	73	C
1657	22	56	91	89	C
1717	50	59	8	16	R
1718	70	74	83	79	C
1734	34	61	0	16	R
1739	66	65	0	24	R
1740	62	77	0	14	R
1780	76	67	73	79	C
1982‡	48	71	46 (48)	63	C
1984‡	66	65	60 (55)	69	C
2007	76	74	78	100	C
2009	60	73	73	84	C
2212	70	76	8	25	R
2360	50	76	4	23	R
2468	60	76	13	24	R
2523‡	80	75	30 (22)	33	R
2700	50	78	76	97	C
2742	40	55	70	100	C
2775	58	67	72	100	C
2816	52	67	11	23	R
2924	56	80	4	26	R
3305	46	71	0	23	R
3306	40	71	95	97	C
3307	56	77	82	100	C
U. 1	54	61	4	8	R
U. 2	70	41	93	88	C
U. 3	42	67	76	97	C
U. 4	68	68	88	74	C
U. 5	50	59	0	15	R
U. 6	58	66	0	13	R
U. 7	42	77	76	80	C

* Includes all post-emergence killing.
† C, stands for Crown, and R, for Royal.
‡ Samples given special comment in text.
§ Figures in brackets are the results of a second test.

The scatter diagram in Figure 3 shows the relationship between the percentages of wilt in the greenhouse and in the field Samples determined as Crown or as Royal form distinct, separate groupings, while samples which are probable mixtures of the two varieties take up intermediate positions.

The mean percentages of emergence and wilt of the 30 samples determined as Crown and the 23 determined as Royal in Table 1 are presented in Table 2.

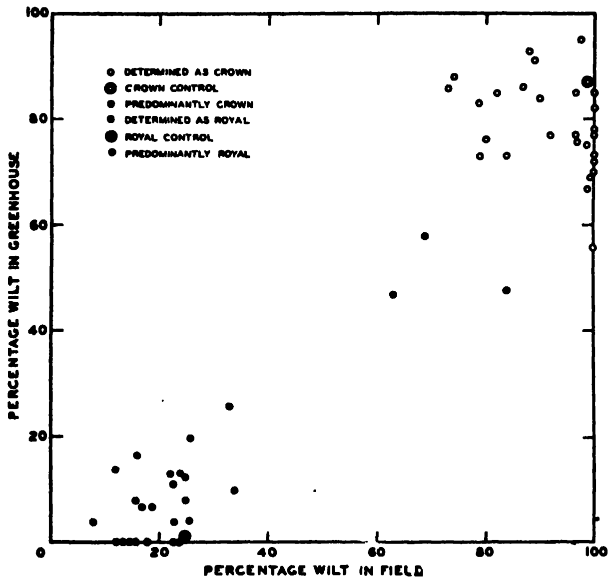

FIGURE 3. Shows the relationship between the percentages of wilt in the Crown and Royal flax samples in the greenhouse and in the field tests as given in Table 1.

TABLE 2.—A COMPARISON OF THE MEAN PERCENTAGES OF EMERGENCE AND WILT OF THE CROWN AND ROYAL SAMPLES AS DETERMINED IN TABLE 1.

Variety as determined	No. of samples	Emergence		Wilt	
		Greenhouse	Field	Greenhouse	Field
		%	%	%	%
Crown	30	57.8	67.2	76.2	90.0
Royal	23	58.3	69.6	7.8	20.2

With few exceptions the percentage of wilt in the field was higher than that in the greenhouse, the average being approximately 13 percentage points higher for both varieties. This may be due in part to the later date at which the survival counts were made in the field, but it in no way interfered with varietal determination. In every instance, the varietal determinations of the samples in the greenhouse agreed with those in the field. Those samples whose determinations were indefinite or about which some doubt existed from the greenhouse results are given special comment in the

text (see above). Some of these are doubtless mixtures of the two varieties, such as samples 1982 and 1984 which are very probably predominantly Crown with a small admixture of Royal.

Pre-emergence killing in the field was lower (10 percentage points) than in the greenhouse, but post-emergence mortality was higher (13 percentage points), for both varieties. That is, if the percentage mortality were based on the number of seeds sown, and not on the number of emerged seedlings as was done in these experiments, the greenhouse and the field percentages would approximate each other more closely. This alternative method would give higher mortality percentage values, since these would include all seeds which failed to germinate regardless of whether the failure were due to parasites or to mechanical injury. The procedure followed, however, is considered to give a more accurate representation of the data sought. The varietal determination of a given sample will be the same no matter which of the two procedures is used in calculating the percentage mortality. The generally drier conditions in the field, however, probably account for the greater emergence. The more heavily suberized endodermis and the difference in composition of cortical cells of the roots of flax seedlings grown in the field compared with seedlings grown in the greenhouse, as reported by Boyle (1), would hardly be factors influencing pre-emergence killing at this early stage. Flor (2), working in North Dakota, found no pre-emergence injury to flax in the field. That field germination of the flax samples was generally lower than the laboratory plate germination in our experiments, is considered as evidence that pre-emergence injury of flax did occur in the field, although the injury was less than in the flax-sick soil in the greenhouse.

The low germination of many of the samples was due mainly to seed-coat cracking, which averaged 38.3% for 20 random samples; and to frost injury, which was slight to severe in 21% of the samples. Forty-two per cent of the samples showed trace to moderate infection with the stem-break and browning organism (*Polyspora Lini* Laff). Of the 58 samples of Crown, 38% were infected, and of the 38 samples of Royal, 47% were infected. These infections possibly reduced germination slightly in a few instances.

Fifteen other undetermined samples were grown in the field in an area only lightly infested with the damping-off and wilt-producing organisms. The procedure was the same as in the heavily infested wilt nursery, except that no counts were taken; instead, varietal identity was recorded by visual examination only and the results compared later with the greenhouse determinations. Here also the field and greenhouse varietal determinations agreed in every instance.

TABLE 3.—A COMPARISON OF THE MEAN PERCENTAGES OF EMERGENCE AND WILT OF 96 FARM SEED STOCKS OF CROWN AND ROYAL AS DETERMINED IN GREENHOUSE TESTS.

Variety as determined	No. of samples	Emergence	Wilt
		%	%
Crown	58	58.2	81.1
Royal	38	60.3	6.0

Table 3 gives the mean percentages of emergence and wilt in the greenhouse tests in all of the 96 samples, 58 of which were determined as Crown and 38 asRoyal. Since the detailed results suggest that 5 of the samples are mixtures of the two varieties, it is reasonable to infer that the mean percentages of wilt in Tables 2 and 3 are slightly lower in "Crown" and slightly higher in "Royal" than they would be if there were no admixtures.

DISCUSSION

The results are very encouraging and strongly suggest that the greenhouse method of determining the identity of Crown and Royal seed samples in flax-sick soil is a reliable one which may be used as a quick service for producers in place of the longer field method. The moderate to fairly high resistance of Royal to the various species and strains of damping-off, blighting and wilting fungi in these soils may possibly not be maintained in other flax-growing areas where climate, soil, and parasitic fungi may be different. Indeed, this contention seems to be borne out by slightly higher percentages of wilt on Royal reported from Eastern Canada and the northern United States than are obtained under our conditions. The testing of the efficacy of the method with wilt-infested soils from other regions at once suggested itself. Paper II of this series presents a preliminary study of the comparative differences in mortality response of Crown and Royal flax in flax-sick soil from Ottawa and from Saskatoon. The greenhouse method, however, should find application as a temporary measure to meet a special situation in Saskatchewan.

There were indications that 5 of the 96 samples tested were mixtures of Crown and Royal. Four of these are shown in Figure 3 in an intermediate position between the distinct, separate groupings of samples determined as pure Crown or as pure Royal. The other mixed sample was one of the 15 grown in the lightly infested area adjoining the wilt nursery on which observational data only were secured. It is not included in Figure 3. Since it is visually impossible to separate the seed of the two varieties and thus determine the purity in the seed laboratory, and since, because of its high susceptibility to wilt it is desirable to discontinue growing Crown, great care should be taken by producers to prevent Royal stocks from becoming contaminated with admixtures of Crown. That mixing can occur all too easily is evidenced by the relatively large number of samples of Crown and Royal in which admixtures of Bison or Redwing seeds are found.

Apparent admixtures of Royal in farm seed stocks of Crown may possibly have been brought about by a gradual increase in the wilt resistance of Crown grown repeatedly on land infested with the wilt organism. Cases in which this may have occurred are considered to be rare. On the other hand, apparent admixtures of Crown in seed stocks of Royal are most probably due to actual mixing, as Royal seed has been commercially available for only three years.

SUMMARY

It has been generally recommended that the growing of Crown flax, because of its high susceptibility to *Fusarium* wilt, be discontinued in

Saskatchewan and that it be replaced by the moderately wilt-resistant variety, Royal. As it is not possible to separate the seed of these two varieties visually in the laboratory, a need arose for a method of ascertaining the identity of undetermined seed stocks of these varieties.

A comparison was made of the percentages of wilt (total plant mortality) in 96 such samples grown in flax-sick soil in the greenhouse and 68 samples in both the greenhouse and the field with the University strains of Crown and Royal as controls. In all cases the varietal determinations in the greenhouse and in the field were in agreement. The results suggest that the greenhouse method can be used as a temporary measure to meet a special situation in Saskatchewan without further implementation by a field test.

ACKNOWLEDGMENTS

Grateful acknowledgment is given to Mr. T. W. L. Burke, Dominion Seed Laboratory, Plant Products Division, Saskatoon, for his willing cooperation and for supplying laboratory help from time to time; and to Dr. J. B. Harrington for space facilities in the wilt nursery, and for many other courtesies.

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STUDIES ON CROWN AND ROYAL FLAX IN FLAX-SICK SOIL

II. COMPARATIVE MORTALITY RESPONSE OF CROWN AND ROYAL FLAX IN TWO DIFFERENT FLAX-SICK SOILS[1]

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Slightly higher percentages of *Fusarium* wilt have been reported on Royal flax grown in wilt nurseries in Eastern Canada, and the northern United States, than have been recorded in the wilt nursery at the University of Saskatchewan, Saskatoon, over a period of years. It is highly probable that the major part of the plant mortality in such soils is due to *Fusarium Lini* Bolley (1), but under certain conditions other pathogenic forms such as *Rhizoctonia Solani* Kühn, *Pythium de Baryanum* Hesse (2), and other *Fusarium* spp., undoubtedly are contributing causes. In a preliminary attempt to check on these differences, a 100-lb. sample of flax-sick soil was obtained from Mr. W. G. McGregor, Central Experimental Farm, Ottawa, at the suggestion of Dr. J. B. Harrington of the Field Husbandry Department, early in the spring of 1943. At the same time fresh samples were collected from the old wilt nursery (on block 505) in which Royal was developed as a wilt-resistant selection from the wilt-susceptible Crown, and from the new 4-year-old nursery (on block 1203). The Ottawa soil was a light loam with pH 7.1 and the Saskatoon soils were silty clay loams with pH 6.7 (block 1203) and pH 6.8 (block 505). Two flats 12 by 18 by 4 inches deep, were filled with each soil sample making a total of 6 flats; these were then sown with 2 rows of Crown and 2 of Royal (Figure 1) and kept in a lightly shaded greenhouse. The temperatures were cool to moderate during the first experiment, late May to July, 1943, and moderate to hot during the second experiment, July to August. The seed consisted of the University strains of these varieties and a first prize sample of Royal from Rosetown, Sask., and a sample of Crown from Kerrobert, Sask. All samples were evidently of high purity as there were no significant differences in percentage wilt between samples of the same variety. To facilitate the condensation of data the two samples of each variety were regarded as one. The combined results of the two experiments are given in Table 1. In series I a total of 180 seeds was sown in each soil, but in series II, the number of seeds was not counted. Emergence counts were made about 2 weeks after sowing, the first count of survived seedlings about 2 to 3 weeks later, depending on temperature conditions, and a second survival count after another 10 to 14 days. In both series the percentage of wilt is based on the number of emerged seedlings.

Royal flax shows only moderate survival (fair wilt, 36%) in the Ottawa soil, while in the Saskatoon soils it shows high survival (slight wilt, 10 to 12%). Crown shows fair survival (66% wilt) in the Ottawa soil, and poor survival (97 to 99% wilt) in the Saskatoon soils (Figure 1). This indicates

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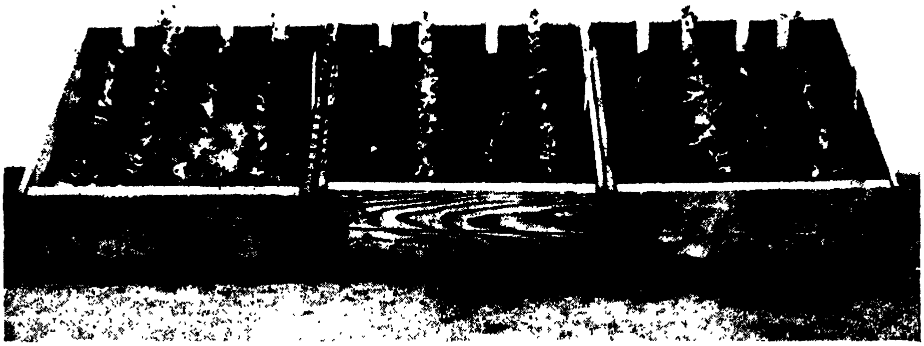

FIGURE 1. Alternate rows of Crown and Royal flax in flax-sick soils; Ottawa soil in flat at left, Saskatoon soil from block 505 at centre, and Saskatoon soil from block 1203 at right. Crown shows less susceptibility to wilt in the Ottawa soil than in the Saskatoon soils, while Royal shows more susceptibility to wilt in the Ottawa soil than in the Saskatoon soils.

TABLE 1.—COMPARATIVE RESPONSES OF CROWN AND ROYAL FLAX TO WILT IN DIFFERENT WILT-INFESTED SOILS IN THE GREENHOUSE*

Variety	Ottawa soil					Saskatoon soil—Block 1203					Saskatoon soil—Block 505				
	Emergence	Survival counts		Wilt		Emergence	Survival counts		Wilt		Emergence	Survival counts		Wilt	
		1	2	no.	%		1	2	no.	%		1	2	no.	%
Series I†															
Crown	166	73	48	118	71.1	153	25	7	146	95.4	149	70	3	146	98 0
Royal	166	116	110	56	33.7	157	153	144	13	8.3	148	131	129	19	12.8
Series II															
Crown	244	144	90	154	63.1	242	85	6	236	97.5	275	108	9	266	96.7
Royal	220	161	137	83	37.7	224	205	198	26	11.6	239	217	212	27	11 3
Total, Series I and II															
Crown	410	217	138	272	66.3	395	110	13	382	99 3	424	178	12	412	97.1
Royal	386	277	247	139	36.0	381	358	342	39	10.2	387	348	341	46	11.9

* Each series represents the combined results of two experiments.
† 180 seeds were sown in each soil in series I.

that the strains or species of pathogenic fungi in the Ottawa soil are more virulent on Royal flax and less virulent on Crown than the strains or species in the Saskatoon soils. In all the flax-sick soils, Crown shows a definite progressive plant mortality up to the final survival count; Royal, however, shows a moderately progressive mortality in the Ottawa soil, but there is only a slight increase in mortality after the first survival count in the Saskatoon soils. This possibly suggests that the killing of Royal in the

early seedling stage in the Saskatoon soils is mainly of the damping-off type (*Pythium* spp. and *Rhizoctonia Solani*), while in the Ottawa soil some other fungus is responsible for the later killing of Royal.

Isolation work from diseased and dead seedlings grown in these respective soils in order to ascertain the causal organisms involved is now in progress.

There was a slight increase in the mortality of seedlings of Crown and Royal in the second experiment in both series I and series II in the Ottawa soil. In the two experiments there were no significant differences in seedling mortality in the Saskatoon soils.

The foregoing findings in general support the contention, already well known in plant pathology and plant breeding, that a plant variety, resistant to a given disease in one region, may not necessarily be as resistant to the same disease in another region.

SUMMARY

The highly wilt-susceptible flax variety Crown and the moderately wilt-resistant variety Royal were grown in the greenhouse in wilt-infested soil from Ottawa, Ontario, and from Saskatoon, Saskatchewan. The results brought out the interesting fact that Crown is relatively *less* susceptible to wilt as expressed in post-emergence percentage mortality, in the Ottawa wilt-infested soil (66%) than in the Saskatoon wilt-infested soil (97%); while Royal is relatively *more* susceptible to wilt in the Ottawa wilt-infested soil (36%) than in the Saskatoon wilt-infested soil (12%), under the conditions of the experiments.

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PASTURE STUDIES No. XXV.

PASTURE SUCCESSION IN THE EASTERN TOWNSHIPS OF QUEBEC[1]

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From the beginning of pasture research in Quebec an ecological survey has been utilized to obtain the fundamental knowledge essential to the development of a rational program of grassland betterment. A background of sward studies can now be referred to in the arrangement and strategic placing of field experiments and in making recommendations. Sufficient information has accumulated during these studies to permit the present discussion of a subject of general pasture interest, succession.

All of the data included here emanates from observations in the Eastern Townships, Appalachian district of southern Quebec, which have served as a testing ground for much of the ecological theory of the provincial pasture surveys. One of the most interesting problems investigated in the Townships has been that of accounting for the seemingly hopelessly confused distribution of swards. Frequently within a restricted area and on the same soil type, all the main swards and intergrades can be seen: a Kentucky blue-white clover pasture may lie across the fence from a red top or poverty grass pasture, while on the next field, red fescue shows typical dominancy. An attempt to resolve this problem was begun in 1941 when swards were studied in relation to various factors. Possibility that the striking soil variation might account for some of the sward variation was not overlooked, and soil maps prepared by Cann and Lajoie (1) showing the different soil types were utilized throughout.

METHODS

As a first step, major soil types were selected and profiles studied in collaboration with soil surveyors. This was very necessary, for soil maps were of a reconnaissance order and at no given point was it possible to be sure of the type without checking. Variation in the type and discontinuous distribution of the soils added to the difficulties. Familiarity with the different soils was obtained only after many profiles had been seen.

Numerous pastures were visited on these major types. The nature and extent of the true sward of grasses and associated weeds were understood and recorded first. Many fields had a remarkably uniform flora throughout, but in others several important sward types would be present suggesting that the sward was undergoing a transition. In these cases all the sward types would be listed and the relative importance of each estimated. The other important groups, such as plants about droppings, plants on hummocks, plants invading, where interesting or informative as

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada. Journal Series No. 187.
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to some particular point, were recorded separately and with source clearly indicated. This is quite a simple procedure, but it suggests certain precautions. There is a tendency for species to be listed indiscriminately and perhaps too thoroughly in ecological pasture work. A lengthy plant list is frequently regarded as an end in itself, resulting in a garbled and meaningless record not capable of intelligent analysis.

Not only was the sward cover read and the soil type verified by digging but the field history was ascertained by enquiry or observation of the field and soil profile. Under history were included notes on former ploughing and cropping, age of the pasture, and fertilizer status.

General Observations

Reference to the condition of the drainage and history of the field is usually sufficient to furnish an explanation for the presence or absence of a sward at any particular pasture site in the Townships. Apparently nothing can be added to the explanation by introducing the soil type concept. Any one of the soil types may bear numerous examples of all the swards except poverty grass, and any one of the swards with the same exception may be found on all the soil types. The varying parent materials permitting the extensive differentiation and mapping of soils seem to have had little influence on the pasture pattern. Drainage which has been utilized as a secondary factor to source of parent material in the classification of soils is of importance, however, in sward distribution. For the present purpose then, it will be sufficient to group the numerous soil types into two divisions, well- and ill-drained.

Field history may have even more importance than drainage in sward distribution. It might be contended that such a factor in effecting changes in flora is also represented by changes in the soil. This may well be perfectly true, yet such soil changes are not of an order sufficient to alter the soil type. Therefore, the only conclusion must be that the reconnaissance system of soil mapping does not offer any explanation of the swards except in so far as drainage is concerned.

The effect of drainage and field history in determining swards may be best illustrated in a discussion on succession. Swards change with length of time under pasture and the succession concept must be introduced in any attempt at explaining cover. Certain schemes based on a simple succession have been advanced in recent years and should be considered.

New York State Pasture Succession—Cooper (3)

(*a*) Kentucky blue and white clover.
(*b*) Kentucky blue, bent grasses, and white clover.
(*c*) Bent grasses and white clover.
(*d*) Bent grasses, sweet vernal grass, and white clover.
(*e*) Sweet vernal grass.
(*f*) Sweet vernal grass and poverty grass.
(*g*) Poverty grass.
(*h*) Herbaceous weeds, shrubs, and trees.

Eastern Townships Pasture Succession—Frankton (5)

(*a*) Kentucky blue and white clover.
(*b*) Kentucky blue, bent grass *Agrostis alba*, and white clover.
(*c*) Bent grass and white clover, or bent grass and Kentucky blue.
(*d*) Bent grass.
(*e*) Red fescue and bent grass.
(*f*) Red fescue.
(*g*) Red fescue and poverty grass.
(*h*) Poverty grass.

Differences between the two arrangements depend largely on differences of flora in the two regions. Under Quebec conditions, sweet vernal grass (*Anthoxantum odoratum*) is infrequent, and, in no sense, part of the succession. Its place is taken by red fescue. The last stage, according to Cooper (2), is "herbaceous weeds, shrubs, and trees", but probably this should not be thought of as the termination of a depletion line but as the type of vegetation that will appear at any time grazing is reduced beyond a certain limit, no matter what the fertility level.

These cycles are, undoubtedly, essentially true although based on superficial observation of swards. No such simple concepts of succession are tenable, however, if drainage and the various details of history are to have full weight, and further subdivision is needed. The pasture succession to be advanced will attempt to introduce a more completely descriptive scheme. Complexity of the problem demands that any explanations suggested for sward changes should be regarded as hypotheses to aid in future investigation rather than as absolute truths.

The varying agricultural practices and land conditions on which these subdivisions depend will require some discussion. A history of ploughing preceding establishment has a marked influence on the immediately succeeding pasture stand and the subsequent cycle. Ploughing and cultivation have hastened deterioration in Township pastures, while old pastures on virgin soils still show a remarkably good cover. Colby (2) has explored the American pasture literature from the earliest writings and his findings are much the same: "because it was observed years later that pastures which were established on cultivated land deteriorated much more rapidly than those which were laid down immediately after the removal of the forest trees. Many of these original pasture areas produced many successive cròps of grass without the aid of soils amendments before èxhibiting any signs of exhaustion." and, "It is not surprising either to find that evidence of pasture deterioration is first found in the early settled portions of the State . . . . . ."

Drainage differences are to be expected in this hilly region. The upland soils usually evidence by colour, brownish or brownish-red, the complete oxidation dependent on good drainage. Ill-drained soils in the lower lying places with poor soil aeration are mottled and darker, usually blackish or grayish. Pasture herbage is evidently not insensitive to the factors promoting differences between the two soil moisture groups.

The successions will be introduced under:

A. Pastures on sites that have never been ploughed.

B. Pastures on sites at some time ploughed and cropped.

(1) Ill-drained.

(2) Well-drained.

Examples are given of the various pastures found at different age levels for each of these groups. It should be realized that only a few samples are possible, that much variation exists, but that the illustrations chosen are intended to depict the true trend. Only fields under the influence of the grazing animal are included and the very few fertilized fields have been omitted.

Pastures on Sites That Have Never Been Ploughed

In the Townships, young pastures on virgin soils and with the biotic factor acting to some degree are invariably under a cover of Kentucky blue-white clover. This is a small scale repetition of what followed on the original introduction of the European pasture plants to northeastern America for both Kentucky blue and white clover were outstandingly aggressive. According to Colby (2), who has reviewed the early literature, white clover became very quickly naturalized and much more so than the grasses.

With the increasing age of pasture, clover decreases and Kentucky blue makes a corresponding gain. Red top is always present to some degree from the beginning and advances steadily. Older fields are usually dominated by this bent, although there are some exceptional fields over a half century in pasture with as much as 70% Kentucky blue and white clover.

Absence of red fescue from these virgin soils in a region where the grass is abundant is one of the most noteworthy features of the first 30 or 40 years. On the uncultivated, ill-drained soils there is little evidence of the grass penetrating on even older fields. To a considerable extent this is also true of the well-drained, yet exceptions occur, and it is highly probable that, with time red fescue would dominate. Large areas of well-drained fields in Shefford and Richmond Counties, evidently too stony for cultivation and of great age, are strongly red fescue. Of course, on abrupt slopes, even on unturned pastures, poverty grass becomes the dominant.

Entrance of Kentucky blue-white clover into the soil exposed by forest removal may well depend on the grazing animal. Dore and Raymond (4) have investigated the seed content of manures from pastures, and find that seeds of these plants are present in high percentages. But red top seed is represented in manure to an even greater degree. Evidently red top is kept in abeyance until some change in conditions, not necessarily of fertility, reduces the original competitive advantage of Kentucky blue-white clover.

The conditions for red fescue succession are described later.

The points discussed can be illustrated by typical examples of swards (Tables 1 and 2). Only the abundant species are mentioned. Red fescue occurred on none of these fields. In both tables all pastures show presence of Kentucky blue and white clover. Table 2 suggests the increasing importance of red top with age.

TABLE 1.—JUVENILE SWARDS—KENTUCKY BLUE-WHITE CLOVER

Survey	146A	146B	189	199	99	53
Soil type	*Greensboro		Coaticook	Greensboro	Calais	Dufferin
Age	5–10 yrs.	15-20 yrs.	5-yrs.	5–10 yrs.	8 yrs.	5 yrs.
	Well-drained		Ill-drained	Well-drained	Ill-drained	Ill-drained
	%	%	%	%	%	%,
White clover	40	15	30	20	20	50
Kb	10	40	40	25	15	22
Red top	—	10	—	15	5	3
Timothy	—	—	—	10	—	—
Weeds, bare, stumps	50	35	30	30	65	35

TABLE 2.—OLD SWARDS—RED TOP

Survey	51B	186B	Line 57	6	54	55
Soil type	Berkshire	Greensboro	Dufferin	Magog	Dufferin	Dufferin
Age	25 yrs.	20 yrs.	60 yrs.	50 yrs.	15–20 yrs.	20–25 yrs.
	Well-drained	Well-drained	Ill-drained	Ill-drained	Ill-drained	Ill-drained
	%	%	%	%	%	%
White clover	2	7	7	3	15	5
Kb	15	3	7	4	20	10
Red top	45	50	50	66	15	35
Phleum	—	—	3	2	—	—
Weeds, bare, stumps	38	40	33	25	50	50

* Complete names and descriptions of the soil types will be found in *Soil Survey of Stanstead, Richmond, Sherbrooke, and Compton Counties*, by D. B. Cann and P. Lajoie (1).

Pastures on Sites at Some Time Ploughed and Cropped

A. Ill-drained

Effect of cultivation on the subsequent pasture flora is quite marked on ill-drained sites. The Kentucky blue-white clover sward of the unploughed fields does not appear and, in the first pasture years after hay, red top is the important grass. Most distinctive feature, and one in complete contrast to the unploughed, ill-drained, is the eventual appearance of red fescue or occasionally brown top. On unusually ill-drained sites, however, red top may remain. Poverty grass never occurs on these ill-drained soils.

Examples of the red fescue type are shown in Table 3.

TABLE 3.—RED FESCUE ON ILL-DRAINED FIELDS OF INTERMEDIATE AGE

Survey	105	10		335A	339	341	36	324A	324B
Soil type	Dufferin	Dufferin		Calais	Dufferin	Dufferin	Magog	Dufferin	Dufferin
Age	20 yrs.	25 yrs. June	October	14 yrs.	30 yrs.	35 yrs.	15 yrs.	30 yrs. Ploughed	25 yrs. Unploughed
	%	%	%	%	%	%	%	%	%
White clover	2	Present	3	2	3	2	5	2	1
Kb	—	Rare	2	Rare	—	—	—	Present	5
Red top	8	Present	Present	15	4	5	2	3	60
Red fescue	60	5	65	46	73	77	60	75	—
Brown top	—	—	—	—	—	—	15	—	—
Timothy	—	—	—	—	6	5	15	—	4
Weeds	10	—	5	10	2	3	3	5	—
Sedges	—	95	5	—	—	—	—	—	—
Bare and moss	20	—	15	25	12	8	18	15	10
Hummocks and cedar	—	—	—	—	—	—	—	—	20

Benefits of intensive grazing on these wetter soils when cultivation has evened the surface are shown in Survey 10. An astounding change in flora has followed the dry summer of 1941 and hard grazing. The distinctive floras of the ploughed and unploughed are particularly well instanced by Survey 324. Bent grasses dominate on the unploughed B, and form a thick ungrazed mat, while A is well-grazed and has a red fescue cover.

Red top may be more abundant in the first years after hay, though sometimes red fescue appears very early when the field has been long in hay. Subsequently, where grazing is intensive enough and the soil not excessively wet. red fescue forms the swards as contrasted to the continuing red top fields of the unploughed. Cultivation probably makes the habitat more suitable for red fescue by permitting better aeration and a more uniform surface, thus eliminating the natural depressions in which red top is more likely to succeed or survive.

Pastures on Sites at Some Time Ploughed and Cropped

B. Well-drained.

The most abundant group of pastures is that on fields that have at some time been ploughed and cropped. Red top is the dominant on young fields of this class.

TABLE 4.—JUVENILE SWARDS—RED TOP

Survey	44	29	102	82
Soil type	Greensboro	Greensboro	Greensboro	Sherbrooke
Age	3 – 8 yrs.	2 yrs.	15 yrs.	15 – 20 yrs.
	%	%	%	%
Kb	Present	Rare	Rare	5
White clover	Present	10	3–4	15
Red top	45	35	55	40
Red fescue	—	—	Occ.	5
Timothy	Present	35	1–2	10
Bare–weedy	55	20	40	25

The early dominance of red top that follows the hay years is soon disturbed for it is a sociable grass, not tufted and rather widely-spaced, and may be easily invaded by red fescue or brown top. Typical patches of red fescue coming into these comparatively new fields have undoubtedly been observed by all pasture workers. Lack of sociability and perhaps more vigorous and early growth under pasture conditions enables the fescue eventually to master the whole terrain, but as field readings show, never completely dispossessing the bent.

Length of time that the sward will be fescue dominant is dependent on the level of fertility, when pasturing began--slope has an effect— but 20-40 years is a fair estimate. These fields are frequently of good size, 20 or more acres, and grazing is remarkably close. Palatability of the grass is clearly greater than that of the bents which are often permitted to head while fescue in the same field is grazed closely. Red fescue lacks sociability and under the close grazing, fills the available space with its shoots and the plant has the highest percentage of ground cover of any of our grasses.

There has been some opportunity to observe the entrance of red fescue more directly. One field (red top 15 years in pasture) in the short period 1939–1942 had an increase in red fescue from a single patch to 20%. Dry seasons might speed the process and two of the years concerned were exceptionally dry. Brown top is locally abundant, and in these regions may frequently form the sward at this stage or earlier. This free-seeding grass appears to be present on younger fields than red fescue. The cattle permit brown top to flower and much more seed must be available in nature. Soil samples examined in the winter of 1941-1942 from below a brown top sward contained 13–15 million seeds to the acre.

TABLE 5.—FIELDS OF INTERMEDIATE AGE—RED FESCUE AND BROWN TOP

Survey	40		250	157A	192	155A	278
Soil type	Greensboro		Berkshire	Sherbrooke	Sheldon	Greensboro shallow	Berkshire
Age	A 15 yrs.	B 25 yrs.	30 yrs.	20 yrs.	6 yrs.	25 yrs.	25 yrs.
	%	%	%	%	%	%	%
Kb	Present	Present	Present	Present	5	—	1
Red fescue	40	45	70	62	5	65	80
Red top	30	5	5	5	5	5	1
Brown top	—	—	—	—	65	—	—
Poverty grass	—	25	—	—	—	Present	—
White clover	—	—	5	3	10	7	—
Weeds—bare	30	25	20	30	10	23	18

Explanation for the tardiness of red fescue entrance might be sought in distribution of seed. Dore and Raymond (4) found that the plant was practically unrepresented in manure samples. Incidentally, the seed is the heaviest by far of the pasture grass seeds, thus reducing motility. Seed content studies in 1941 (unpublished) of soil samples from below red fescue swards revealed that seed was practically non-existent. The plant is

grazed so hard that the amount of seed produced must be comparatively small. The patches, generally circular, of this grass in the early stages of its entrance suggest that spread is largely a vegetative matter. This is one phase of the cycle where it would be rash to state that reduced fertility engendered a change of sward. Differences in dissemination and production of seeds seem to be a more reasonable explanation.

Even when seeded, red fescue attains its maximum performance quite late. In Germany (7) a seeding planned to give: *Trifolium repens* 40%; *Lolium perenne* 25%; *Poa pratensis* 17%; *Festuca rubra* 18%; resulted in a very different stand. After two years *Lolium perenne* occupied 57% of the terrain and the other grasses smaller areas than expected. *Poa pratensis* dominated a few years later, giving way eventually in the ninth year to *Festuca rubra*. In the development of a pasture sward without seeding, *Festuca* might be expected to make even slower ingress for the reasons stated in the preceding paragraph.

The end of the pasture cycle on cultivated fields finds poverty grass the dominant (Table 6). These fields are generally old—50 years or more, but may be much younger. At the final stage of the cycle it is noteworthy that red top which has persisted throughout the red fescue period, still remains, although often red fescue has been eliminated entirely. Survey 300 is a good example of the transition stage between red fescue and poverty grass. Rather more than half of the field is under poverty grass.

TABLE 6.—OLD FIELDS—POVERTY GRASS

Survey	300		199	95B	246
Soil type	Greensboro		Greensboro	Greensboro	Berkshire
	(Red fescue)	(Poverty grass)			
Age	35 yr.	35 yr.	60 yr.	30 yr.	50 yr.
	%	%	%	%	%
Red fescue	60	18	—	—	—
Poverty grass	2	38	65	70	75
Other grasses and clover	7	3	—	5	1
Weeds	10	10	10	Few	9
Bare and moss	21	31	25	25	15

Undoubtedly, severe cropping practice prior to pasturing accelerates the pace of the cycle. In Stanstead County, the old-settled districts, exemplified by Brown's Hill, Dufferin Heights and East Hatley, are marked by a greater proportion of poverty grass pastures than in the County as a whole. The moraine ridges were cleared early following the pioneer custom of removing the hardwood to make potash for ready funds. Soil conditions were undoubtedly more amenable than in the valleys, as was air drainage, and cultivation proceeded actively. Many of the fields now under poverty grass were probably placed under pasture only when further seeding of hay or grain seemed profitless. Amendments were not employed to any great degree, and the years of cultivation would exhaust the soil far more than pasturing. Poverty grass has been recorded from only a

very few uncultivated fields. Considering the age of some unbroken fields, it will be a long time before the swards pass through the closing stages of the succession.

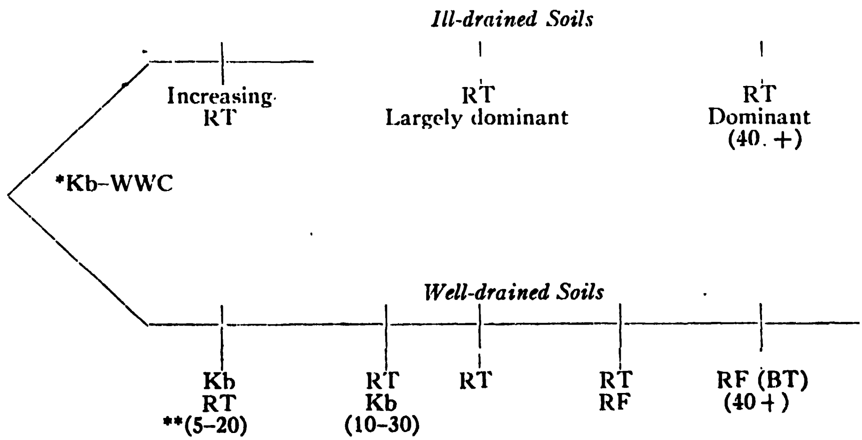
DISCUSSION

Attention has been drawn to the sward complexity in pastures of the Eastern Townships. Widely different swards, such as Kentucky blue-white clover, red top, red fescue and poverty grass, may be seen on the same soil type and in adjacent fields. Investigation has revealed that, although environmental factors, climatic conditions and soil type, may be similar, differences exist in field histories and drainage.

When many such instances have been studied, certain generalities appear. Kentucky blue-white clover precedes all other swards on the new fields that have never been ploughed. This is true of all types, both ill-and well-drained. Red top follows the rich clover sward though eventually the unsociable, yet gregarious, red fescue or brown top take over. On the oldest fields, particularly when cultivation has preceded pasturing, poverty grass becomes the dominant.

Cultivation has a marked effect on subsequent pasture swards. Edaphic factors have changed; aeration in the ill-drained soils has been bettered, the fields are smoother, available minerals and organic matter are reduced. Ill-drained soils, in permanent pasture for several years have a cover of red fescue or brown top on fields that have, at some time, been ploughed, while virgin soils of the same age are under red top. Well-drained soils soon run out to poverty grass after cultivation has exhausted fertility resources, but far better swards remain on the unturned soils. These concepts have been incorporated in the following diagrams of the hypothetical pasture cycles.

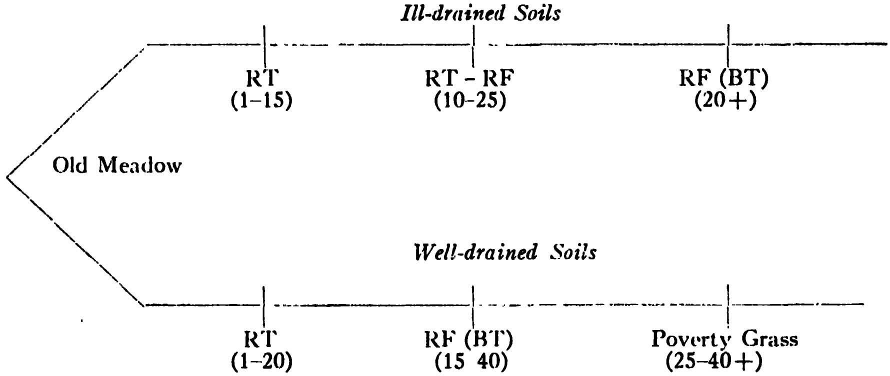
Pastures on sites that have never been ploughed:



*Kb	=	Kentucky blue
WWC	=	Wild white clover
RT	=	Red top
RF	=	Red fescue
BT	=	Brown top

**These figures represent years from the beginning of pasturing. In this scheme it is suggested that the sward concerned, Kb–RT, will appear at the earliest, after 5 years, and will be succeeded by RT–Kb not later than 20 years after the establishment of the pasture.

Pastures on sites at some time ploughed and seeded:



The question regarding the correlation of edaphic changes with these sward changes, remains. Cooper (1932) exploded the idea that increasing acidity was linked to pasture deterioration. Determination of pH from many samples of soils from below a wide range of sward types revealed no significant differences. In Stanstead, on this survey, poverty grass was seen growing quite actively on limy ridges.

Changes in pasture cover in the succession are usually supposed to follow on changes in the fertility level. Cooper concludes that exchangeable cations both in quantity and quality are of greater significance in influencing distribution of pasture plants than the hydrogen ion. Other workers agree and Robinson (1937) finds, "the primary chemical properties limiting the percentage of Kentucky blue and white clover in the pasture studies are percentage base saturation and available phosphorus."

The trend is in the direction of soil depletion on most pasturelands today, so that the succession is normally a retrogression from the agricultural viewpoint. However, it is accepted that the cycle is reversible and that the cover can be graded upwards by proper manuring and management without the use of seeds. This concept may, in the main, be correct, but for some phases, perhaps too much has been assumed. It has been observed in the Townships that fertilized red fescue swards remain largely as before, though higher yielding and perhaps even more palatable. Poverty grass cannot always be made to yield ground by mineral application. According to Frankton and Raymond (6), there are probably 40 square miles of poverty grass pasture in Stanstead County (430 square miles area) that would not respond.

Those writers who stress the fertility cycle, omit all reference to a factor which has been responsible for much of the deterioration: former cultivation. Effects of turning are manifold. Not only are the mineral elements depleted, but destruction of the organic matter accumulated under the original forest is hastened. Without reference to the laboratory, the observer easily notes that poverty grass soils are of poor structure, probably dependent on lack of properly decomposed organic material. The soil seems to be of single grain structure and difficult to wet. In contrast, the unploughed ground on which Kentucky blue-white clover flourish is rich in organic matter.

A further point should be emphasized. Pasture succession is usually considered as dependent on fertility changes. This may, in part, be fallacious. The red top to red fescue phase is not necessarily governed by fertility so much as by seed, and propagation factors. Red fescue seed, for various reasons, appears to be far less abundant in nature than red top or Kentucky blue seed, and accordingly, is more tardily introduced into pasture fields where it is largely confined to a vegetative extension.

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DOWNY MILDEW DISEASE OF CAULIFLOWER SEED PLANTS[1]

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Downey mildew (*Peronospora Brassicae* Gäum.) is a common parasite of cruciferous plants, but it has not been considered of much economic importance except in seedlings and in cabbage intended for shipment and storage. Recently an interesting phase of this disease was observed in British Columbia, where numerous cauliflower plants of the Snowball variety were made almost worthless for seed production owing to infection of the curd. Infection of the seedlings in cold frames and of the foliage of plants grown in the field has been observed during previous years in many localities. This year, a systemic type of infection involving the main stems and the curd was found in numerous plants where most of the curd parts were stunted, having failed to elongate into normal inflorescences (Figure 1). This stunting of the curd is somewhat similar to that associated with systemic downy mildew infection of terminal and lateral shoots in other hosts such as hops and legumes.

A constant symptom of this type of infection is a dark purple discoloration of the surface of the stems of the curd, which often appears in broad longitudinal streaks. Affected tissues were slightly shrunken, and conidiophores and conidia were usually present on the infected stems and leaflets. The internal tissues were also discoloured (Figure 1), this discoloration appearing as dark grey necrotic specks and areas throughout the tissues. This has been found in the main stems as well as in the stems of the curd. When infected tissues of the main stems and the curd were examined microscopically, mycelium and dichotomous haustoria of the downy mildew organism were found in the parenchyma and pith. The lobed haustoria were very prevalent within the cells, and were similar to those found by Gardner (1) in turnip roots.

Ramsey (2) who reported the disease on cabbage in storage, claimed that considerable loss was occasioned by bacterial soft rot and Alternaria rot following the infection by Peronospora.

In the Pacific Coast areas of British Columbia where cauliflowers are grown for seed, losses due to curd rot caused by various factors are often very considerable. This usually occurs when the curd is well developed, but before the floral parts begin to elongate. After the plants have passed this stage, the growers claim that the critical period for curd rot is over.

In order to test the pathogenicity of the downy mildew on the curd, a few small cauliflower plants were inoculated outdoors in October. This was done by placing leaves of cabbage seedlings bearing conidia of the downy mildew, both on the surface and among the inner parts of the curd. A few plants were set aside as checks. All the plants were watered periodically so as to insure ample moisture for spore germination.

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After approximately three weeks, the surface of the curd of the inoculated plants assumed a dirty white to a brown colour, while the colours of the surface and of the internal tissues of the curd stems were dark purple and dark grey respectively, like those observed in the field. The mycelium of the fungus was found in the terminal tissues and in the stems of the curd.

FIGURE 1. A longitudinal section through the main stem and curd of a cauliflower seed plant showing stunting of the floral parts and discoloration of the stem tissue induced by *Peronospora Brassicae* Gäum., with a normally developed shoot on the left.

In about 6 weeks after inoculation, the infected curd was shrivelled, stunted and brown in colour. Under the prevailing environmental conditions the fungus seemed to have a drying effect on the tissues. By this time, secondary organisms were present on the terminal parts of the infected curd. The curd of the check plants was white and firm and of normal appearance. When the first symptoms of browning appeared, it was noticed that the

curd remained slightly moist after spraying with water, while the water particles would not adhere readily to the surface of the curd of the check plants. The former condition should favour the germination and development of secondary organisms.

Insect pests such as flea beetles, thrips and aphids are usually prevalent on seed plants in the field. In several fields inspected, flea beetles were causing lesions on the curd as well as on the foliage, thus facilitating the entry of the downy mildew and other organisms. Some of these insects undoubtedly act as spore carriers.

Weber (3) claims that the control of downy mildew on cabbage can be obtained best by spraying the seedlings in the seedbed with Bordeaux mixture, to which a spreader and sticker, such as calcium caseinate, has been added and that spraying should commence as soon as the first leaves begin to develop. In order to avoid transferring the disease into the field, it is recommended that cauliflower seedlings be sprayed in the above manner and since the fungus can thrive on other cruciferous hosts, these should also be sprayed or eradicated. If the disease should appear on cauliflower seed plants in the field during the curd stage, it is recommended that they be dusted with copper lime dust every 10 days until the floral parts are well developed. Simultaneously, the insect pests must be kept in check by the application of insecticides.

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AMPHIDIPLOIDY IN *TRITICUM-AGROPYRON* HYBRIDS[1]

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[Received for publication December 30, 1943]

The first successful attempts at hybridizing wheat and *Agropyron* grasses were made in the U.S.S.R. by Tzitsin in 1930. This work was carried on vigorously until the advent of the present war. Their chief aim has been the creation of perennial wheat, and fair success has been claimed in this respect.

In 1935 *Triticum-Agropyron* hybridization and breeding work was initiated at the Division of Forage Plants, Ottawa, the Forage Crops Laboratory, Saskatoon, and the National Research Council, Ottawa. The former two institutions undertook the hybridization and breeding work while Dr. F. H. Peto of the National Research Council, Ottawa, assisted materially in the early years of the project by cytological work and investigations on artificially induced polyploids.

The earlier breeding work on this project has been reported by Armstrong (1), Johnson and McLennan (5), Johnson (4), and White (17). The cytological investigations have been reported by Peto, (9, 10, 11), Peto and Boyes (12) and Peto and Young (13).

The two *Agropyron* species which we succeeded in crossing with various tetraploid and hexaploid wheats are *A. glaucum*, a hexaploid with $2n = 42$, and *A. elongatum*, a decaploid with $2n = 70$. Wheat crossed with the latter yielded partially fertile hybrids which we have carried on by line breeding methods. On the other hand crosses with *A. glaucum* yielded only sterile hybrids. To overcome this sterility we backcrossed the F_1 extensively with wheat. The crossing success was extremely low, being only 0.24 per cent. Cytological examination of the backcrosses by Peto (11) disclosed that in the first generation the observed chromosome number approximated that expected if unreduced female gametes were fertilized by normal haploid wheat gametes. The plants were in effect triploids. From a breeding standpoint they proved very unstable segregating rapidly into annual types. Of the few lines we have been able to carry through to stability for perennialism the seed more nearly approaches wheat in size than the selfed lines. They are also, much more readily threshed.

PRODUCTION OF AMPHIDIPLOIDS BY COLCHICINE TREATMENT

Another method of inducing fertility in the sterile glaucum hybrids is the doubling of the chromosome complement by artificial means. In 1937 Peto (10) doubled the chromosome number of Kharkov × *A. glaucum* through the application of alternating high and low temperature treatments on the early zygotic divisions. Colchicine treatment of the F_1 seeds or plants has proven more successful than heat treatments in inducing chromosome doubling. Raw (14), Sears (15), Peto and Boyes (12), Thompson

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et al. (16), and Berg and Oehler (2) have reported the production of amphidiploids of *Triticum* × *Agropyron*, *Triticum* × *Aegilops* and *Triticum* × *Secale* by the colchicine method.

A wide range of methods of securing chromosome doubling by the use of colchicine has been described by many workers. These methods involve varying the concentration of the drug, varying the duration of treatment and varying the stage in the plant's life cycle at which the treatment is applied. In 1941 we carried on some experiments in treatment methods having 4200 F_1 seeds from various *Triticum* × *A. glaucum* crosses available for experiment.

Five general types of treatment are listed in Table 1. All treatments were carried out at a temperature of 70° F. Within each type, variations were made in the concentration and duration of the time of the treatment. After the treatment the seed was washed, planted in trays and after a few weeks the surviving seedlings were transplanted to pots and later transferred to the field nursery. When the plants head and ripen they are carefully examined for fertile spikes. The fertility may be confined to only part of a spike or to one or two spikes per plant. Only infrequently are all the spikes of a plant affected. This criterion of fertility as an indication of chromosome doubling is quite reliable when it is recalled that F_1 diploids are completely sterile. Also heads with less than 3 seeds per head were not regarded as amphidiploids.

TABLE 1.—COMPARISON OF RESULTS OF VARIOUS METHODS OF COLCHICINE TREATMENT—1941

Lot No.	No. of seeds	Colchicine		Survival				Amphidiploids	
		%	Duration	6 weeks		7 months		No.	%
				No.	%	No.	%		
Series 1—Treatment of dry seeds									
1	197	.1	24–27 hours	69	35.0	59	29.9	1	0.51
2	8	.1	42	0	0.0	0	0.0	0	0.00
3	555	.2	18–27	257	46.3	228	41.1	9	1.63
4	151	.2	48	44	29.1	43	28.5	4	2.65
5	358	.4	24–27	108	30.2	107	29.9	11	3.07
6	40	.4	45	18	45.0	16	40.0	2	5.00
7	152	.6	16	17	11.2	17	11.2	2	1.32
8	97	.6	24	9	9.3	9	9.3	2	2.06
9	10	.6	45	3	30.0	3	30.0	0	0.00
10	60	.8	24	4	4.7	4	4.7	0	0.00
Total	1626			529	32.6	486	29.9	31	1.91
Series 2—Treatment of germinated seeds									
11*	200	.2	18–24 hours	55	27.5	53	26.5	5	2.50
12**	30	.2	18–24	4	13.3	4	13.3	0	0.00
13*	40	.2	6	18	45.0	16	40.0	3	7.50
14*	30	.4	24	4	13.3	4	13.3	0	0.00
15*	10	.6	24	0	0.0	0	0.0	0	0.00
16**	20	.6	18	0	0.0	0	0.0	0	0.00
Total	330			81	24.5	77	23.3	8	2.42

* Germinated for 18–24 hours
** Germinated for 24

TABLE 1.—COMPARISON OF RESULTS OF VARIOUS METHODS OF COLCHICINE TREATMENT—1941 —*Concluded*

Lot No.	No. of seeds	Colchicine		Survival				Amphidiploids	
		%	Duration	6 weeks		7 months		No.	%
				No.	%	No.	%		
Series 3—Plumule immersion									
17	48	.4	21 hours	32	66.7	32	66.7	1	2.08
18	67	.6	22	40	59.7	39	58.2	5	7.46
Total	115			72	62.6	71	61.7	6	5.22
Series 4—Germinated seed treated in partial vacuum									
19	124	.2	15 min.	63	50.8	63	50.8	11	8.87
20	834	.2	30	452	54.2	408	48.9	69	8.26
21	101	.2	45	700	69.3	61	60.4	3	2.97
22	136	.2	60	54	39.7	53	38.9	4	2.94
Total	1194			639	53.5	585	49.0	87	7.29
Series 5—Treated in .2% 24 hrs. followed by partial vacuum									
23	44	.2	30 min.	35	79.5	31	70.5	4	9.09
24	50	.2	10	23	46.0	23	46.0	2	4.00
25*	9	.2	30	5	55.6	5	55.6	3	33.33
Total	103			63	61.2	59	57.3	9	8.74
* Treated in .2% 42 hours									
Total	3368			1384	41.1	1278	37.9	141	4.19

The successful use of the first or dry seed method was first reported for the Gramineae by Myers (8). By this method the dry seed is placed in petri dishes and moistened with aqueous solutions of colchicine varying from 0.1 to 0.8%. The duration of treatment varied from 18 to 48 hours. A concentration of 0.1 had little effect while at the other extreme of 0.6 to 0.8 the seedling mortality was very high. The optimum treatment in this series appears to be 0.4% colchicine applied for 24 hours.

In series 2, the seed was first germinated 1 to 2 days on water-moistened filter paper in the petri dishes before treatment. The use of this method with cereal grains was reported by Dorsey (3) in 1939. It will be noted that the germinated seed is more sensitive to injury since a 0.4% concentration which was the optimum in dry seed treatment killed 87% of the seed while a 0.6% concentration was quite lethal. The optimum in the series appears to be treatment 13, which is 0.2% concentration for 6 hours.

In series 3, the seed was germinated until the plumules were ½" to 1½" long. The seedlings were then tied in bundles and suspended in a 0.4 to 0.6% solution for approximately a day. Here the 0.6% solution was quite effective, killing comparatively few plants and producing 7% amphidiploids. The advantage of this method is that the roots are kept clear of the solution and consequently there is less root injury.

In series 4, the partial vacuum method was applied to germinated seeds. A treatment of 15 to 30 minutes appears quite effective judging from the high percentage of amphidiploids produced. Treatment 22 indicates that if it is carried on for an hour the percentage seedling survival drops. This is the method which we consider to be the most effective.

Series 5, is a type of double treatment. The dry seeds were first treated 1 day with 0.2% then washed and allowed to germinate until the plumules showed and finally given a 15 to 30 minute treatment at 0.2% in partial vacuum. The results show this method to be quite effective.

In the material listed in this table it will be noted that the number of seeds tested for each treatment varied widely. This was because of the desirability of keeping the various lots of crossed seed intact. A considerable number of small lots of less than 10 seeds each are not included in the table. They were treated uniformly according to treatment 11.

Table 2 shows the frequency of amphidiploids obtained from F_1 seed of different female wheat parentage. None were obtained from *T. vulgare* × *A. glaucum*, *T. persicum* × *A. glaucum* or *T. timopheevi* × *A. glaucum* crosses, although amphidiploids had previously been obtained from the two former crosses. Hybrids of *T. diccoccum*, *T. durum* and *T. turgidum* female parentage have yielded the bulk of our amphidiploids. It is possible that in tetraploid wheat × *A. glaucum*, chromosome doubling can be induced more readily than in hexaploid × *A. glaucum*. It is more probable that it is a question of the relative competing ability of doubled and undoubled cells in the two amphidiploid types.

TABLE 2.—FREQUENCY OF AMPHIDIPLOIDS OBTAINED FROM VARIOUS *Triticum* × *A. glaucum* CROSSES—1941

Triticum female parent	Seeds treated	Survival after 7 months		Amphidiploids	
	no.	no.	%	no.	%
T. vulgare (4)	18	1	5.5	0	0.00
T. diccoccum (4)	243	54	22.2	6	2.47
T. durum (5)	1609	628	39.0	28	1.74
T. turgidum (4)	1775	654	36.8	102	5.74
T. pyramidale (3)	404	101	25.0	7	1.73
T. timopheevi (1)	147	52	35.4	0	0.00
T. persicum (1)	13	2	15.4	0	0.00
Total	4209	1492	35.4	143	3.40

TABLE 3.—AMPHIDIPLOIDS PRODUCED FROM *Triticum* × *A. glaucum* CROSSES

Wheat species	Variety	Year	Breeding no.	Present status
T. vulgare	Moseida	1939–40	S-108	F_4 ; testing and mult.
	Kharkov	1937	S-147	F_4 ; testing and mult.
T. diccoccum	Vernal	1938–39	S-91	F_5 ; testing and mult.
	Khapli	1940–41	S-132	F_2 selection
T. turgidum	No. 49	1939–40	S-107	F_4 ; testing and mult.
	Mirable	1940–41	S-137	F_2 selection
	Pseudocervium	1940–41	S-140	F_2 selection
T. durum	Akrona	1940–41	S-125	F_2 selection
	Kubanka	1940–41	S-128	F_2 selection
	Mindum	1940–41	S-131	F_2 selection
	Pentad	1940–41	S-134	F_2 selection
T. pyramidale	119328	1940–41	S-145	F_2 selection
T. persicum	Black Persian	1940–41	S-148	F_2 selection

DESCRIPTION OF AMPHIDIPLOIDS

Table 3 lists the amphidiploids that have been produced since 1937. These fall into two groups as far as breeding procedure and present status are concerned. The first group consists of the two strains S-108 and S-147 obtained from hexaploid wheats, and two strains, S-91 and S-107 from tetraploid wheats. These strains have been multiplied without any individual plant selection and are in the fourth or fifth generations. The second group derived from tetraploid wheat × *glaucum* crosses since 1941 are in the second generation. A few of the most fertile plants in each F_2 population were selected this past summer and these will be established as F_3 lines in 1944. (Figures 1 to 3).

Since all the amphidiploids have the common parent, *A. glaucum* the differences that exist between strains are largely due to morphological differences in the various wheat parents. These differences are quite marked. Comparing S-108 and S-147 the *vulgare* derived strains, several characters are seen to differ widely.

Character	S-108	S-147
Awning	Awnless	Strongly tip-awned
Spike density (10 central internodes)	105.5 mm.	87.5 mm.
No. of florets per spikelet	6 – 8	3 – 4
No. of seeds per spikelet	2.0	1.2
Width of non-flowering glumes	Wide throughout	Narrow at base
Attachment of flowering glumes	Strongly attached	Medium strong attachment
Rachis brittleness	Quite brittle	Medium tough
Threshability	Glumes attached to seed	Seed mostly free

While there are these differences apparent between strains they exhibit certain similarities. All appear to have about the same degree of winter-hardiness. The survival for the various strains during the past three winters ranged from 80 to 100% and did not alter appreciably from generation to generation. All are susceptible to winter injury from ice sheeting

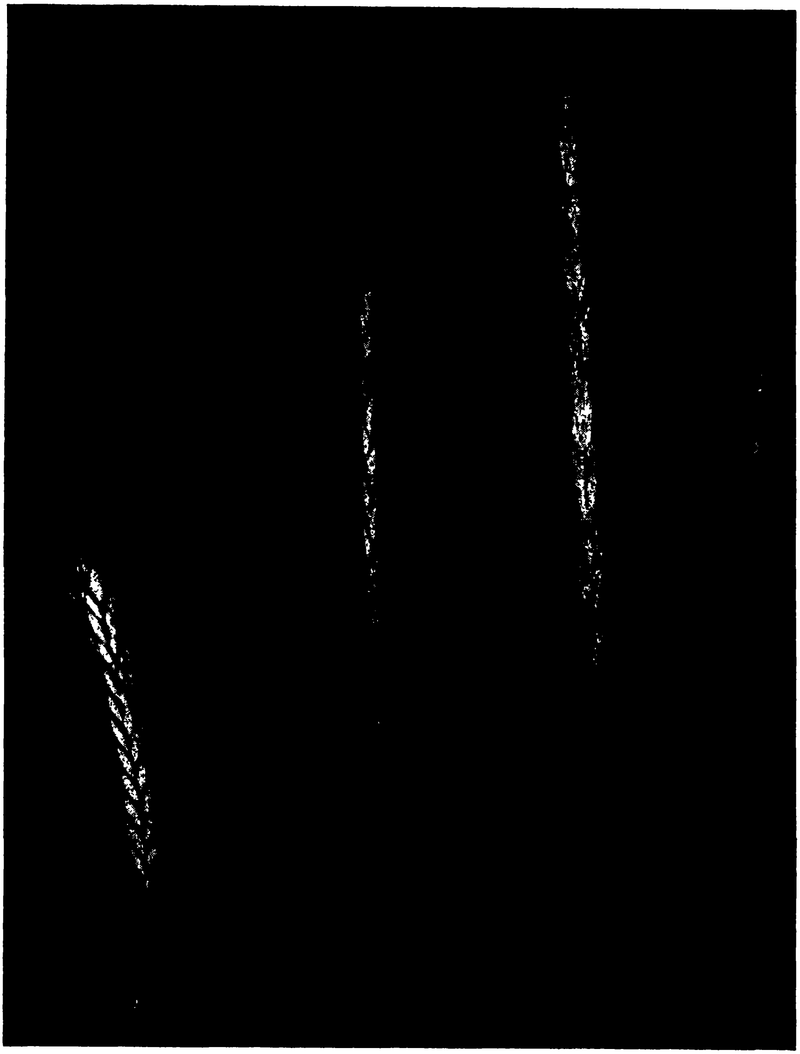

FIGURE 1. Heads of Vernal Emmer × *A. glaucum* hybrids and parents. Left to right, Vernal emmer, sterile F_1 diploid, fertile F_2 amphidiploid and *A. glaucum*.

which was very severe on the plots in 1941-42. The perennial grasses such as timothy and Kentucky bluegrass are not greatly affected by this type of injury.

Most of the strains possess a fairly brittle rachis when ripe which may cause loss through shattering. This weakness may be overcome by harvesting slightly on the green side and allowing the grain to ripen in the

stook. Upon threshing there is usually a resulting mixture of free seed and seed with the glumes attached. If the concaves are set close to the cylinder to get a better separation much breaking of the slender seed occurs. The most satisfactory method appears to be to thresh with the glumes attached as this seed passes readily through the drill runs.

A. glaucum spreads moderately by stolons and this character is largely retained in the amphidiploids. This spreading propensity should prove of considerable value in forming a good sod and adding fibre to the soil. The four most advanced strains and several standard grasses were seeded in a replicated test this past summer in order to get some comparative data on forage yield next year. Besides the differences between strains there is also

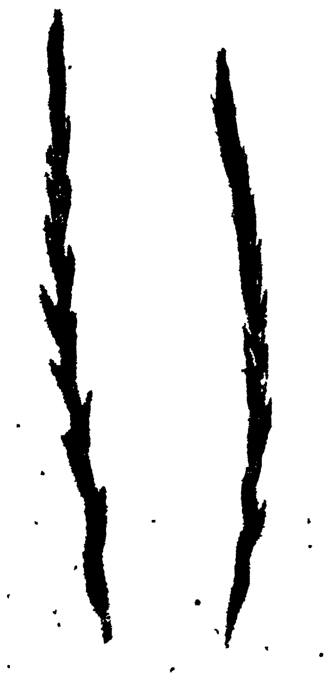

FIGURE 2. Heads of hexaploid wheat × *A. glaucum* hybrids. Moseida × *A. glaucum* left and Kharkov × *A. glaucum* right.

considerable variation between individual plants within a strain. This is especially true with regard to fertility. In a study of a random sample of 20 heads of S-91 the spike density was found to be 104.2 ± 2.01 mm. with a C.V. of 9.47% while the fertility per 10 spikelets was found to be 26.8 ± 1.16 with a C.V. of 19.44%. This high variability in fertility appears to have a cytological basis as will be shown later.

One of the requirements of the hybrid is that the seed will contain enough stored food to enable seedlings to emerge when planted at a depth of several inches. A depth of seeding test was conducted in the greenhouse to compare S-91 with wheat, *A. glaucum*, and crested wheat grass. The weight of 1000 seeds were: S-91, 22.8 gm.; vernal 34.2 gm.; Dawson's

TABLE 4. SEEDLING EMERGENCE OF GRASSES AND WHEATS SEEDED AT DIFFERENT DEPTHS

Material	Wt. per 1000 seeds (gm.)	½″	1″	1½″	2″	2½″	3″	3½″	4″
A. cristatum	1.8	60	90	95	35	10	0	0	0
A. glaucum	5.7	95	100	95	80	75	65	25	25
Vernal	34.2	89	83	56	50	61	83	83	78
D. G. Chaff	44.3	100	100	100	100	100	100	80	100
S-91	22.8	100	100	94	100	100	94	67	50

FIGURE 3. Increase block of Kharkov × *A. glaucum* amphidiploid. June 23, 1942.

Golden Chaff, 44.3 gm.; *A. glaucum* 5.7 gm.; and *A. cristatum* 1.8 gm. Seeds were sown at depths varying from ½″ to 4″. Results of the experiment given in Table 4 show that seeding emergency of S-91 was as good as wheat at depths of ½″ to 3″ but was not as good at greater depths. The emergency of the two grasses dropped gradually at depths exceeding 1½″. These results seem to indicate that S-91 can be seeded at a depth comparable to that used for wheat, hence it should be much easier to establish than crested wheat grass, which must have shallow seeding.

CYTOLOGICAL INVESTIGATIONS

The cytology of the F_1 diploid generation of *Triticum* × *Agropyron* hybrids was investigated and reported by Peto (9) in 1936. He found in the F_1 of tetraploid *Triticum* × *A. glaucum* ($2n = 35$) an average of 29-22 univalents and 5-6 bivalents. The pairing of the bivalents was usually very loose, the attachment being end to end. The pairing did, however, indicate a partial homology between sets A or B of *Triticum* and one of the sets derived from glaucum. In the F_1 of hexaploid *Triticum* × *A. glaucum* where $2n = 42$ the amount of pairing approximated that found in the F_1 tetraploid wheat × glaucum. The set of chromosomes (C) introduced from the Vulgare parent was not homologous to a set from glaucum.

In the period 1941-43 the cytology of a small group F_2 plants and their F_3 progenies has been studied in the amphidiploid, *T. turgidum* × *A. glaucum.* In an amphidiploid of this parentage the $2n$ number would be 70 made up of 2 sets of wheat chromosome and 2 sets of glaucum and theoretically there should be perfect pairing, wheat *inter se* and grass *inter se.* The chromosome number might be expected to remain constant at 70 in the succeeding generations. Cytological examination did not bear out this latter supposition. A summary of the chromosome associations found in 5 F_2 plants is given in Table V.

TABLE 5.—CHROMOSOME ASSOCIATIONS IN F_2 PLANTS OF S-107

Plant no.	Chromosome associations of				Total chromosome no.
	1	2	3	4	
78	7.6	28.0	.33	.33	66
154	5.3	31.3			68
166	4.9	29.4	.10		64
292	4.0	20.0			64
435	5.0	32.0			69
Average	5.4	29.7	.10	.05	66.2

The five plants had $2n$ numbers of 64, 64, 66, 68 and 69. We may therefore deduce that in the F_1 parent plant the chromosome pairing was imperfect leading to chromosome loss in the male and female gametes. The pairing in the F_2 was also imperfect, 2-10 univalents being found in each cell examined. Trivalents and quadrivalents were also occasionally found. The tetrads of young pollen were for the most part regular and matured a high proportion of viable pollen.

DESCRIPTION OF TEXT FIGURES

FIGURES 4 – 11. Late diakensis and first metaphase of F_2 and F_3 plants of *T. turgidum* × *A. glaucum.*

FIGURE 4. F_2 plant 107–78, 11 × I, 26 × II, 1 × III.

FIGURE 5. F_2 plant 107–78, 4 × I, 29 × II, 1 × IV.

FIGURE 6. F_3 plant 107–166–5, 1 × I, 27 × II, 2 × III.

FIGURE 7. F_3 plant 107–435–8, 1 × I, 32 × II, 1 × III.

FIGURE 8. F_3 plant 107–435–2, 31 × II, 1 × IV.

FIGURE 9. F_3 plant 107–166–5, 30 × II, 1 × V.

FIGURE 10. F_3 plant 107–154–4, 1 × I, 30 × II, 1 × III, 1 × VI.

FIGURE 11. F_3 plant 107–154–13, 29 × II, 1 × III, 1 × VII.

Magnification of figures is × 690.

Peto and Boyes (12) also examined five F_2 plants from the comparable amphidiploid, Vernel Emmer × *A. Glaucum*. The $2n$ chromosome numbers were found to be 64, 68, 69, 70, and 70, a somewhat higher range than our F_2 group. About the same prevelance of univalents and multiple configurations were also observed.

The failure of all chromosomes to pair cannot be attributed to a lack of homology. On the other hand we know that pairing may be affected by extremes in temperature, genetic factors or conditions disturbing the cytodynamics of the cell. The latter is the more probable cause of lack of perfect pairing in amphidiploids as suggested by Kostoff (6). The double number of chromosomes in a cell of inadequate dimensions might disturb the pairing of homologues at the zygotene stage. There might also be a competitive effect in the set of 7 wheat and 7 glaucum chromosomes, which F_1 diploid studies showed to be partially homologous, which would prevent all wheat and all glaucum chromosomes pairing. Such weak pairing if it did occur might not be capable of persisting until late diakenesis and metaphase leaving the early partners as univalents. (Figures 4 to 11.)

Small F_3 progenies from the selected F_2 plants were also studied cytologically. The results are given in Table 6.

Pairing of chromosomes in the F_3 generation was more complete than in the F_2. This is shown in the fewer number of univalents per cell which averaged 2.2 for the F_3 and 5.4 for the F_2. It is also shown in the increased tendency to form multiple configurations of 3 and 4 chromosomes and more rarely larger associations of 6 and 7.

The F_2 averaged 1 trivalent per 10 P.M.C. while the F_3 averaged 2 per 10 cells. The F_2 averaged 1 quadrivalent per 20 cells while the F_3 averaged 4 quadrivalents per 20 P.M.C. The F_3 progenies had an average chromosome number of approximating that of their respective F_2 parents. There is no pronounced tendency to revert to a lower chromosome number.

The improved pairing in the F_3 generation over that of the F_2 may be considered significant and might be explained in part on the basis of improved or better adjusted cell dynamics and in part to the competitive elimination of male F_2 gametes with unfavourable chromosome combinations.

TABLE 6.—CHROMOSOME ASSOCIATIONS IN F_3 PLANTS IN S-107

Plant no.	Chromosome associations of							2n number
	1	2	3	4	5	6	7	
78 – 1	1.4	29.4		.4				61
(66) 2	1.0	33.0						67
3	3.3	30.8						65
4	.3	31.8	.7					64
7	3.2	29.5	.2					63
11	2.0	29.6		.5				64
12	.3	31.5	.3					64
14	3.6	21.5	.5					64
19	2.8	30.4	.2	.2				65
Average	2.1	30.4	.2	.1				64.1

TABLE 6.—CHROMOSOME ASSOCIATIONS IN F_3 PLANTS IN S-107—*Concluded*

Plant no.	Chromosome associations of							2n number
	1	2	3	4	5	6	7	
154 – 2	3.4	30.9	.4	.1				67
(68) 4	1.7	32.5	.3			.3		70
5	.5	32.7						66
7	2.8	32.3	.5					69
8	2.2	32.8	.2	.4				70
9	1.0	32.0		.3				66
10	1.5	30.7		.3				64
11	2.3	32.3						67
13	1.3	31.6	.3				.3	68
14	2.7	32.5	.2					68
15	4.0	31.5						67
Average	2.1	31.9	.2	.1		.02	.02	67.4
166 – 1	3.0	33.0						68
(64) 2	2.6	32.4	.2					68
4	2.5	30.2		.3				64
5	3.7	28.0	.3	.7		.2		65
7	2.2	30.6		.4				65
8	3.7	31.0		.3				67
10	1.2	28.3						58
Average	2.7	30.3	.1	.2		.04		65.0
292 – 3	1.6	32.3	.2	.2				66
(64) 4	1.6	31.0	.4	.4				66
6	1.0	32.3		.4				67
7	3.2	29.2	.2					62
9	4.4	29.8	.2	.4				66
Average	2.4	30.9	.2	.3				65.4
435 – 1	1.6	31.6	.6					67
(69) 2	.4	31.4		1.0				66
3	1.2	34.0	.2					70
4	1.7	29.5	.7					63
5	1.3	32.3				.2		63
6	1.4	32.6	.4	.2				66
7	1.0	34.5						70
8	2.3	32.0	1.0	.3				70
Average	1.4	32.3	.3	.2		.02		67.3
Average	2.2	31.2	.2	.2		.02	.01	65.8

TABLE 7.—FREQUENCY OF PLANTS WITH VARIOUS NUMBERS OF SEEDS PER SPIKELET

F_3 progeny of	F_2 chromosome no.	0	.1 – .4	.5 – .9	1.0–1.4	1.5–1.9	2.0–2.5	Ave.
78	66	4	1	3			1	.45
154	68		1	1	4	5		1.29
166	64		3	1	2	1		.81
292	64	2			2	1		.82
425	69	1	1	2	1	3		.99

Notes were taken on the F_3 plants at maturity as to height, tillering, density of spike, awning and fertility. The distribution of the F_3 progenies in regard to fertility is given in Table 7. This is expressed in number of seeds per spikelet which was measured from the 10 central spikelets. It will be noted that the distribution in regard to fertility is quite variable ranging from 0-2.2 seeds per spikelet. Also that the progenies of the higher chromosome parents have the highest average fertility. Correlating the fertility of the 39 F_3 plants with their chromosome numbers, the coefficient of correlation was found to be 0.55 ± 0.112 which is moderately high and significant, 15 F_3 plants had 65 or less chromosomes and of these 2 had 1.4 and 2.2 seeds per spikelet while the other 13 had less than 0.6; 24 F_3 plants had 66-70 chromosomes and of these 16 had more than 1.2 seeds per spikelet while 8 had less than 1.2. It is apparent that low chromosome segregates as a rule are of a low grade fertility while the higher chromosome segregates have appreciably higher fertility.

In regard to the other agronomic characters such as height, tillering, and leafiness there was no correlation found with chromosome numbers. This is in keeping with the common observation of sterile F_1 diploids which as a rule are vigorous, tall and leafy.

DISCUSSION

A fairly analagous case of amphidiploid behaviour has been reported by Thompson, Britten and Harding (16); F_1 plants from the cross *T. turgidum* ($n = 14$) $\times$ *A. speltoides* ($n = 7$) were treated with colchicine yielding a small proportion of 42-chromosome amphidiploids which in many respects resembled *vulgare* wheat. The chromosome number and behaviour was studied in 53 plants selected at random from F_2, F_3, and F_4 generations. About 30% of the plants were found to differ from the normal expected chromosome number of 42 by 1 or 2 chromosomes. The great majority of the P.M.C. in 42-chromosome plants showed some unpaired chromosomes as well as associations of 3 and 4. It was also noted that plants with divergent chromosome numbers were not as fertile as those with the normal number.

This relationship between chromosome number and fertility is important from the practical breeding viewpoint. Even while increasing the amphidiploids without line selection as we are doing with the earlier productions, natural selection will work in our favour by eliminating the less fertile, lower-chromosome types. On the other hand deliberate selection of lines on the basis either of fertility or of high chromosome number as we are doing with the newer productions, will tend to produce stable breeding material.

SUMMARY

Sterility in *Triticum* $\times$ *A. glaucum* hybrids was overcome by inducing chromosome doubling by means of colchicine treatments of the F_1 seed.

Several methods of applying the colchicine are detailed and the effectiveness of the various methods is shown by the data on the percentages of amphidiploids secured.

In a cytological study of a group of F_2 plants and their F_3 progenies, chromosome pairing and stability was found to be improved in the third generation over that of the second.

A significant correlation was found in the third generation plants between chromosome number and fertility. This relationship favoured stabilization at the higher chromosome numbers.

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THE MIRID, *CALOCORIS NORVEGICUS* GMELIN, A STRAWBERRY PEST IN NOVA SCOTIA[1]

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For several years it has been observed in Nova Scotia that good stands of healthy-appearing strawberry plants would flower profusely but the berries would fail to develop or would form so-called "nubbins" or "buttons". Various explanations were proposed by growers and technical agriculturalists which included, among other things, incomplete pollination, frost, lack of fertility, drought, winter injury, root rot, tarnished plant bug, virus diseases and others. While the authors are not prepared to state that any or all of these factors may not at times be responsible, they now believe that the mirid, *Calocoris norvegicus* Gmelin, is the most frequent cause of malformed fruit of the strawberry in Nova Scotia.

For some years the strawberries at the Dominion Experimental Station at Kentville had been producing very poorly and "nubbins" frequently formed the greater proportion of the crop. It was the general opinion of the officials at the station that the soil on which the strawberries had been grown for a number of years had become "diseased" or "run out", and so in 1938 a plantation was set out in a new location. In 1939, when the Superintendent, Mr. A. Kelsall, showed it to the senior author, it supported a fine stand of plants which had borne a heavy bloom. In raising the clusters of half-grown berries to examine the conformation of the fruit numerous small greenish mirid nymphs were noted and some of the fruits were beginning to show malformations. It was at that time suggested to the Superintendent that this insect might be "stinging" the young fruits and thus causing them to be mis-shapen. Subsequent observations on this field showed that the malformed fruits increased in numbers and severity with the result that the crop was almost a complete failure. Observations on a nearby plantation the following year by Dr. J. M. Cameron, Provincial Entomologist, and Mr. Kelsall served to strengthen the suspicion that this insect was the causal agent of the malformed fruit.

Observations in numerous fields were made in 1941 and 1942 by field men of the Nova Scotia Department of Agriculture and some experiments on control of the insect were inaugurated in 1942 by officers of the Experimental Station, the Provincial Department of Agriculture and the Dominion Entomological laboratory, Annapolis Royal. In 1943 the junior author was employed practically full time during the summer on a detailed study of this insect and its relationship to strawberry malformations. Studies made by him with potted strawberry plants under cages in the greenhouse have proved beyond reasonable doubt that this insect causes fruit malformations similar to those found in many strawberry plantations throughout this province.

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Distribution of the Insect and Plants Attacked

Although it has been known that this insect was prevalent in many strawberry plantations in Kings County for the past two or three years, no attempt was made to survey the other strawberry growing areas in the province until the summer of 1943. All the principal producing areas are now known to be infested and the typically malformed fruits were found in all cases corresponding in severity to the prevalence of the insect.

It is not known whether the insect attacks the strawberry in other areas outside Nova Scotia, but it probably does. Knight (1) records it as "a European species now known from Connecticut, Maine, Massachusetts, New Jersey, New York, Nova Scotia, Quebec, where it occurs on grasses." An examination of references in the Review of Applied Entomology indicates that it is widespread in Europe where it is a pest of more or less minor importance on potato, beets, sugar beets, horse beans, beans, peas, flax, hemp, chrysanthemum, hops, red clover, apple, pear, young leaves of strawberry plants and cucumbers in greenhouses. It has been suggested that it is a vector of potato viruses but there is evidently some question as to the validity of this.

In Nova Scotia, in addition to strawberries, adults have been taken in numbers on sheep sorrel, tansy, alsike clover, red clover, timothy, garden beans, Swedes, mangolds, garden beets, wild radish and meadow fescue, and less commonly on parsnip, carrot, garden peas, buckwheat, potato, Canada blue grass and raspberry. Sheep sorrel, *Rumex acetosella* L., is the most common host, and it is thought that the prevalence of this plant in and about strawberry plantations may be an important factor in respect to injury to the strawberry fruits.

A few eggs of the insect have been found in the stems of sheep sorrel in the field. When caged on strawberry plants adults oviposited in the stems, and they probably also do so under field conditions. Lafferty *et al.* (2), reporting on the bionomics of this insect in Ireland, stated that it deposited eggs on corn marigold (*Chrysanthemum segetum*), ragwort, thistle, charlock, redshank, etc. Further studies are necessary to determine the plants selected for oviposition in Nova Scotia.

Life History

No detailed studies of the life history have been carried out in Nova Scotia. The small nymphs are found on strawberries when the earliest fruits on early varieties are about half grown. Probably for this reason these early fruits usually show less injury than the later ones. Adults begin to appear about the time the plantation is producing ripe fruit and continue to mature for at least 2 weeks. As soon as the adult stage is reached the insects leave the strawberry and probably disperse to the plants mentioned previously. Nymphs are often very common on sheep sorrel but no studies have been made to determine other plants on which they occur. Field observations suggest that the insect overwinters in the egg stage, and that there is but one generation a year.

Control

A satisfactory method of control has been found by growers who did not know that an insect was responsible for the fruit malformations. In the Masstown area in Colchester County where this type of injury has been prevalent on strawberries for at least 10 years, the senior author was shown fields in 1935 on which the straw mulch had been burned in the early spring. There appeared to be little doubt but that the quality of the fruit was better on these burned fields than on fields where the mulch had been handled in the customary manner, i.e., where it had been removed from the plants and placed between the rows. The practice of burning the mulch in the spring has now been adopted as standard in this district although the growers had not been aware of the true reason for the production of better fruit.

While the reason for the beneficial effects of burning the mulch has not been definitely established it appears probable that the heat of the fire destroys the overwintering eggs which have been deposited in the stems of the strawberry plants and weeds.

When it appeared that the injury found on strawberries in Kings County was similar to that at Masstown it was decided to try burning the mulch and arrangements were made to carry over a heavily infested field at the Experimental Station from 1941 to 1942. This field received a heavy mulch of oat straw in the fall of 1941, and under the supervision of the Superintendent, one-half was burned over in April under almost ideal conditions. Since the mulch was heavy the burning was deep and for a time it appeared that the plants were permanently injured. However, they improved rapidly later and by harvest time were fully as good as the non-burned area although possibly a little later. Observations made during the growing season clearly showed that nymphs of *Calocoris norvegicus* were much more numerous on the unburned than on the burned area. In the early part of the season none could be found on the burned area but they gradually migrated in, possibly from the sheep sorrel and other weeds in the surrounding areas as well as from the section of the plantation on which the mulch was not burned. Without going into details regarding injury to the various varieties included in this test it may be stated that, for the Senator Dunlap variety which appears very susceptible, on the burned area 48.1% of the fruits were free of malformations. Of those injured 32% showed slight, 29% moderate and 39% severe injury. On the unburned area, the same variety showed only 0.5% free from injury and of those injured 2% has slight, 2% moderate and 96% severe injury. Of the other varieties in the test only Claribel, a very late variety, showed any marked degree of resistance, with 26.3% of the fruits free of injury on the unburned area. There are some indications that varieties which ripen before or after Senator Dunlap may not be so susceptible to injury as the latter. The variety Premier (Howard 17) appears to be somewhat less susceptible to injury than Senator Dunlap; this, together with its earliness, probably accounts for the increasing popularity of Premier. This earlier ripening is possibly responsible for the lesser amount of injury even when in the same plantation.

The possibility that the insects or their eggs may be transported into strawberry plantations with the mulch, or that the mulch would protect the insects already in the plantation during the winter, was carefully

investigated. It was found that there were no significant differences in the degree of infestation following mulching with new oat straw, old oat straw, upland hay, salt marsh hay, spruce boughs and apple tree prunings. Leaving the plantation unmulched over the winter does not appear to be helpful in all cases although apparently it may sometimes reduce the infestation.

Sprays or dusts cannot be recommended at present with any degree of confidence. Extensive laboratory tests show that satisfactory kills may be secured by using nicotine sulphate, 1 pint per 100 gal.; anabasine sulphate, 1 pint per 100 gal.; pyrethrum, 3 lb. per 100 gal., and a commercial pyrethrum extract[4], 1 pint per 100 gal.; to each of which was added 4 lb. of laundry soap or soap flakes. The addition of hydrated lime, 4 lb. per 100 gal., to the nicotine sulphate spray did not give a satisfactory kill. A number of commercial wetting and penetrating agents used in combination with both the nicotine sulphate and pyrethrum were not as effective as the soaps. Nicotine sulphate with strongtly alkaline soaps showed the most promise.

The results were unsatisfactory from field plots where pyrethrum and nicotine sulphate dusts were applied with a power driven cranberry type duster with a trailing dragsheet about 30 feet long.

Nicotine sulphate, 1 pint per 100 gal., to which was added 4 lb. of strongly alkaline laundry soap or soap flakes has given some promise under field conditions. However, it is necessary to apply this spray very heavily and with high pressure under practically ideal conditions. The trouble appears to be to get the insects adequately wetted with the spray as they are very active and drop to the ground at the least disturbance. As there is always a good deal of litter about the bases of the plants it takes a great deal of spray to wet this sufficiently to make contact with all of the insects.

In the laboratory tests there appeared to be little difference between small or large nymphs in susceptibility to sprays; nevertheless, it is suggested that under field conditions spraying should be started early where the insect is numerous since most of the injury is done to the blooms or to the small fruits and becomes more marked as the fruit increases in size. This fact is likely to give the impression that the injury is done as the fruits near maturity. Two or more applications may be necessary to give satisfactory control and only highly efficient power sprayers would be effective.

Since burning the mulch is not considered good horticultural practice and since the majority of strawberry growers do not have power sprayers, and in many cases there are no power sprayers available for miles around, it is felt that other methods of control should be investigated.

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[4] One U.S. gal. contains extractives equivalent to 20 lb. pyrethrum flowers assaying 0.9% pyrethrins.

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COMBINING BEAUTY WITH UTILITY IN ROSE BREEDING[1]

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The remarkably high ascorbic acid content of the fruit or hips of many species of rose is now well known, and particularly in Great Britain, Europe and Russia vast quantities of rose hips are harvested annually as a food supplement rich in vitamin C. The U.S.S.R. scientists, Iwanoff and Bukin (1), pointed out in 1937 that the flesh of freshly harvested hips of the rose species, *R. cinnamomea* and *R. acicularis* as grown in the northern and middle parts of the U.S.S.R. contained as high as 4·6% ascorbic acid and that the southern species, *R. canina*, contained 2·2%. Pyke and Melville (2) investigated the ascorbic acid content of the common rose species of Great Britain and likewise found that in general the northern species contained the highest content of ascorbic acid. These authors divided the rose species into four groups based upon the ascorbic acid content of the fresh fruit pulp exclusive of the seed.

TABLE 1.—THE ASCORBIC ACID CONTENT OF THE ROSE SPECIES OF GREAT BRITAIN

Group	Mg. per 100 gm.	Group	Mg. per 100 gm.
Group 1		Group 3	
R. Afzeliana	1000	*R. agrestis*	460
R. coriifolia	1080	*R. micrantha*	400
R. mollis	1260	*R. spinosissima*	340
R. Sherardi	1260	*R. obtusifolia*	420
Group 2		Group 4	
R. canina	550	*R. arvensis*	80
R. dumetorum	590	*R. stylosa*	190
R. tomentosa	690		

Analyses revealed that the flesh of the hips of the commonest roadside species in the coastal regions of B.C., namely, *R. nutkana*, contained 1200 to 1370 mg. ascorbic acid per 100 gm., a content equivalent to or slightly higher than the values in the high group in Pyke and Melville's list for Great Britain.

An enquiry by a British Columbia nurseryman led to the analysis of a number of rose hybrids of local origin. The ascorbic acid values in Table 2 were obtained by the method of Ballentine (3) and are contrasted with the content of *R. nutkana* and *R. gymnocarpa* (two native species); *R. Moyesii* (a parent of *Rosa Eddieii*); Hoosier Beauty (a horticultural variety) and the flesh of freshly harvested ripe tomatoes.

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TABLE 2.—THE ASCORBIC ACID CONTENT OF A NUMBER OF ROSE HYBRIDS, TWO ROSE SPECIES FROM THE COAST OF B.C., HORT. VAR., HOOSIER BEAUTY, AND RIPE TOMATOES*

	Ascorbic acid Mg. per 100 gm.
Rose hybrids	
1. *Rosa Eddieii*	2780
2. *R. rugosa* hybrid	35 (mouldy)
3. *R. rugosa* hybrid	505
4. *R. rugosa* hybrid	633
5. *R. rugosa* × *canina*	123
6. *R. rugosa* hybrid Kitania	792
7. *R. rugosa* × *canina* hybrid	98
8. *R. canina* (Bröogs)	222
9. *R. Moyesii* × *nutkana*	1240
10. *R. multiflora* hybrid	56
11. *R. canina* (Bröogs) × *rugosa*	123
12. R. "Sweet Briar" (Macdonnell)	223
Rose species	
R. nutkana	1266
R. gymnocarpa	246
R. Moyesii	2383
Rose variety	
"Hoosier Beauty"	171
Tomato variety	
"Best-of-all" (ripe)	30

* Expressed as mg. per 100 gm. flesh as harvested.

The high ascorbic acid content of the hips from hybrids No. 1 and No. 9 were of particular interest, and an enquiry revealed that both were derived from the same cross, namely, between the common coastal species *R. nutkana* and *R. Moyesii*. Since the hips of hybrid No. 1 contained more than double the ascorbic acid content of *R. nutkana* it was of interest to discover later that the other parent, *R. Moyesii*, as grown near Vancouver contained 2383 mg. per 100 gm. of flesh, a content almost as high as the hips of hybrids No. 1, registered at Ottawa as *Rosa Eddieii*. It was also of interest that the hips of this hybrid were over twice the size of those of the native parent *R. nutkana*, and that the flesh was softer and much more palatable than the native species. Also, the seeds were fewer in number and larger in size and could be removed more easily from the flesh which is an advantage for jam making purposes.

Although the hips of *Rosa Eddieii* were slightly larger and more palatable than those of its parent *R. Moyesii*, nevertheless in type and general appearance they were very similar.

These studies are suggestive that the high ascorbic acid content of the hips of certain rose species together with characteristics that affect their palatability can be retained in a rose breeding project thus combining beauty with utility.

SUMMARY

The possibilities of combining beauty with utility in rose breeding is illustrated by the high vitamin C (ascorbic acid) content of the hips of the hybrid rose registered at Ottawa as *Rosa Eddieii*. The hips of this hybrid

contained 2·7% ascorbic acid based upon the fresh weight. The hybrid was a selection from a cross between *R. nutkana*, a B.C. coast species and *R. Moyesii* each containing an exceptionally high ascorbic acid content, namely, 1·3% and 2·3%, respectively.

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UTILIZATION OF CROP RESIDUES FOR WIND EROSION CONTROL[1]

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The severe dust storms throughout the semi-arid regions of North America during the years 1931 to 1938 focused the attention of agricultural workers on the problem of preventing erosion of the soil by wind. The general concern over this problem was aroused not because wind erosion was new, for it has occurred throughout many years in the past, but because the extent of the areas involved and the magnitude of the damage was far greater than during any previous period.

Previous to the period just mentioned little attention had been given to the prevention of wind erosion of soil. Particularly in the drier regions, where a large proportion of the cultivated land had to be fallowed each year for reasonable assurance against drought and consequent crop failure, large tracts of land were left bare and unprotected from high winds. Absolutely no attention had been given in many instances to the adoption of methods of farming that would reduce the devastating effects of wind. Throughout many years of production of grain crops the straw was usually removed off the land and much of it burned. Tillage practices likewise were generally such as to leave the soil bare and highly pulverized.

However, major progress in wind erosion prevention and control has been made in recent years through such practices as the development and widespread application of strip farming and the retention of crop residues at the surface of the ground (1, 6, 7). The maintenance of crop residues on cultivated land has been facilitated partly by a substantial increase in the use of combine harvesters which leave all the straw scattered on the land, and partly by considerable progress made in development, improvement, and application of tillage implements that leave all crop residues at the surface of the ground. The widespread utilization of the vegetative litter, commonly called "trash cover" in Canada and "stubble mulch" or "straw mulch" in the United States, is the most promising agricultural development in recent years. Not only has it been of value in overcoming the serious effects of wind, but has proved to be very effective in controlling water erosion, improving the water-holding capacity of the soil, and reducing surface evaporation (5, 8).

Although the beneficial influence of crop residues as a preventive measure against wind erosion has been widely recognized, no information except a preliminary report of the present investigation (4), was available

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on the actual reduction of wind erosion produced by different types and quantities of crop residue incorporated in the soil. The purpose of the study reported in this paper was to obtain detailed data on the influence of amount, degree of burial, and nature of crop residue on the erosiveness of different soils. It was hoped that this study would lead to the establishment of some definite numerical relationship between the crop residue factor and wind erosiveness.

MATERIALS AND METHODS

Sixteen widely different soils, comprising 8 distinct morphological types, were used in the experiments. The soils were taken to 4-inch depth from fields of summerfallow containing little or no undecomposed organic matter. For comparison, one sample of Haverhill loam was highly pulverized. In addition to these, clean dune sand, obtained from active dunes, and fresh loam drift were used. The fresh drift represented that portion of the soil which had been moved about by wind over Haverhill loam and deposited against various obstructions. It was composed of erosive particles only and had all the physical characteristics of dry dune sand.

The soils, protected by different amounts of crop residue ranging from 0 to 4 tons per acre, were first thoroughly air dried and then placed in a trough 12 feet long, 21 inches wide and 3 inches high and exposed to a uniform air stream in a wind tunnel. The tunnel had a test chamber 15 feet long, 2.5 feet wide and 2 feet high, equipped with a propeller driven by a variable speed electric motor. The velocity of wind, ranging up to 35 m.p.h., could be easily controlled by a rheostat. All velocity gradients up to 9 inches in height at the leeward end of the exposed area fitted well into Prandtl's logarithmic formula and had all the characteristics of the natural wind up to similar height in the field.

The quantity of soil eroded during each test was determined by weighing the trough with its contents before and after exposure to the wind. In these experiments it was not possible to make accurate determinations of the amounts of erosion less than 0.05 kilograms per square metre of exposed soil. However, this amount of erosion occurring during the first 3 to 5 minutes of exposure to high wind in a tunnel can be considered negligible for all practical purposes.

The soils were exposed to a 17- and a 22-m.p.h. wind as measured at 12 inches above the ground. The former velocity is comparable to a moderate natural wind at which considerable movement of erosive soil becomes apparent, whereas the latter velocity corresponds to a high natural wind, often accompanied by severe dust storms.

Wheat stubble of different lengths and wheat straw that had gone through the threshing machine were the crop residues used. In one case the residue was scattered on the surface, in the other it was mixed into a definite depth of surface soil. In still another case it was anchored by pushing the straw ends or the stubble crowns to 2-inch depth at an angle of 45 degrees with the wind. In the second case about one-half and in the third about five-eighths of the 8-inch stubble was above the surface of the ground.

EXPERIMENTAL RESULTS

The Influence of Strawcover on Wind Velocity and Intensity of Erosion

Figure 1 shows the velocity of wind at different heights over straw covered and bare soil surface, and the relative amounts of soil removed during exposure to a uniform air stream in the laboratory wind tunnel. Large differences in the amounts of eroded soil were entirely due to the type of ground surface, for the structure of the soil was identical throughout the whole series of exposures. The results show that short straw, as it

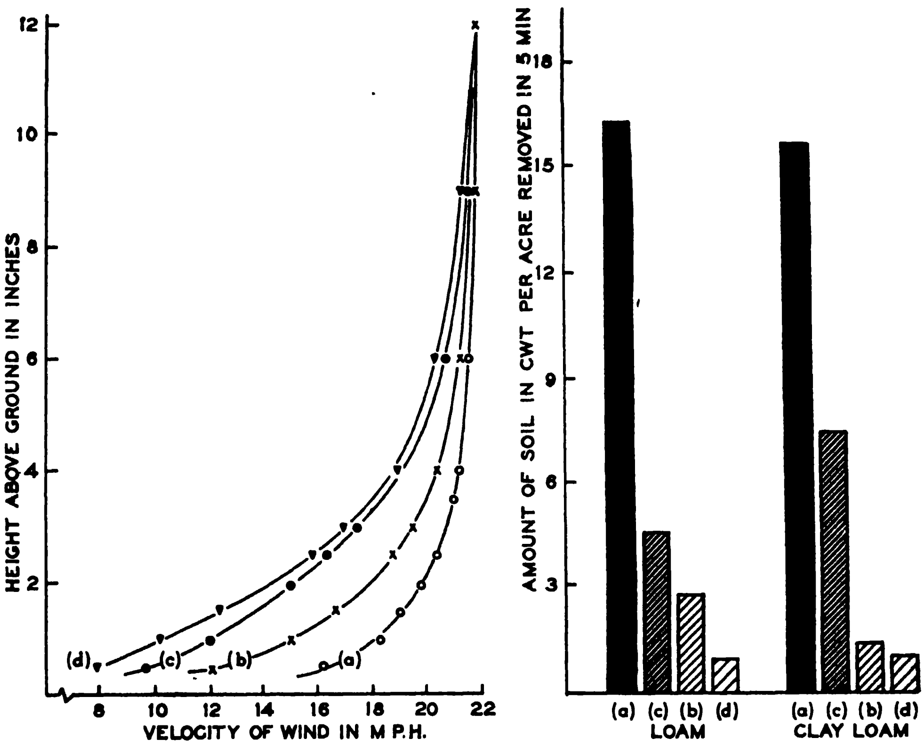

FIGURE 1. Wind velocities at various heights above ground and amounts of soil eroded off (a) a smooth, bare ground, (b) same as (a) with 0.5 ton of wheat straw worked into the surface, (c) ridges 1.25 inches high, 7 inches wide, at right angles to the wind, and (d) ridges as in (c) with straw as in (b).

came from the threshing machine, worked uniformly into the surface to a maximum depth of 2 inches, markedly reduced both the velocity of the wind and the erosion of the soil. The reduction in wind velocity was greatest near the surface of the ground, becoming progressively less with height, and reaching zero at approximately 1 foot of height. Thus, at ½-inch height the velocity over a smooth surface was reduced from 16.1 to 12.0 m.p.h. as a result of mixing one-half ton per acre of wheat straw into the surface of the ground. But at 2 inches above the ground the reduction was only half, and at 5 inches only an eighth of what it was at half-inch height. Somewhat similar, though not as pronounced, reductions in wind velocity were obtained by incorporation of straw to a ridged instead of a smooth soil surface. In other words, the straw was somewhat less

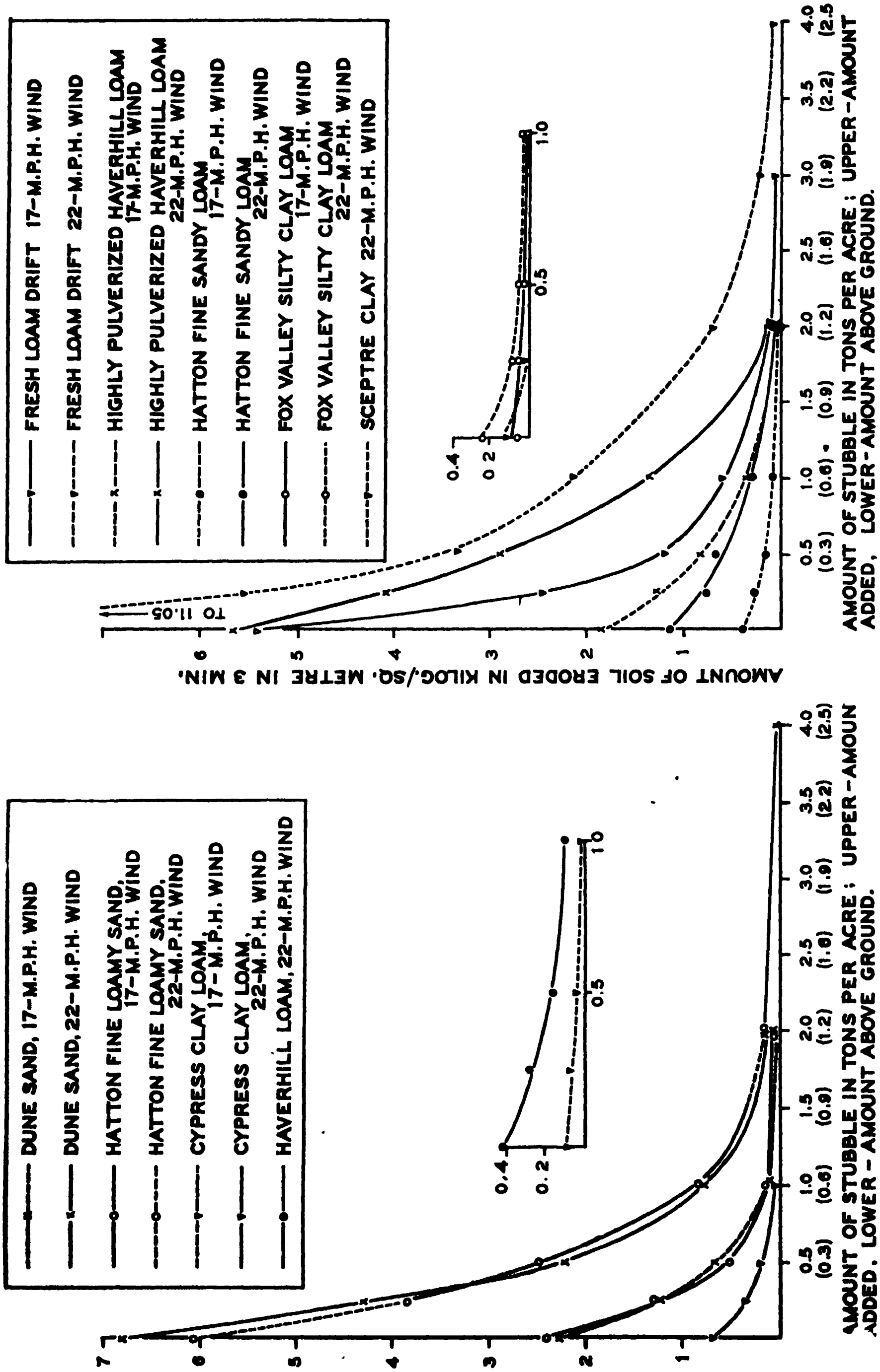

FIGURE 2. Relation between wind erosion and the amount of evenly distributed wheat stubble partially worked into the ground. Eight-inch long stubble was anchored into the soil surface by pushing the crowns down to 2-inch depth at an angle of 45 degrees with the wind.

effective in reducing wind velocity over a ridged than over a smooth surface, but the combined effect of straw and ridges was appreciably greater than the effect of straw or ridges alone.

The effect of the straw on erosiveness was very appreciable on both loam and clay loam soil. Thus, when the amount of soil eroded off a smooth, bare condition averaged 16.2 cwt. per acre during 5 minutes of exposure to wind, that eroded off a smooth, straw covered surface averaged only 2.1 cwt. per acre for the same period. Likewise, when the amount of soil eroded off a ridged, bare surface amounted to 6.0 cwt. per acre, the amount eroded off a similar surface to which straw had been added amounted to 1.0 cwt. per acre for the same period of exposure. In these cases the one-half ton per acre of wheat straw, half of which was above the ground surface, reduced the amount of erosion by 83 and 88%.

The Influence of Amount, Length and Degree of Burial of Crop Residue on Wind Erosion

Figure 2 shows the effect of different amounts of stubble on the erosiveness of 9 widely different soils. It is shown that the intensity of erosion was reduced most markedly by the first increment of stubble added to the soil surface, but each succeeding increment became less and less effective. The relationship between crop residue and the amount of erosion is, therefore, not a linear relationship but a logarithmic type, for when the amount of crop residue is plotted against the logarithm of amount of eroded soil, the curve of erosiveness, as shown in Figure 3, becomes a straight line. It is shown that the slope of the straight line curves is not the same in every case, indicating that the stubble is not equally effective on all soils. The curves for the soils tested indicate that erosiveness q for any given wind velocity can be expressed by

$$q = \text{antilog}_{10}(x - Cy)$$

where x is the logarithm of the amount of erosion of the soil unprotected by crop residue, and which is indicated by the position at which the erosion curves of Figure 3 meet the ordinate, and y the amount of stubble over the surface of the ground. C is a constant which appears to vary somewhat with different soils and, as will be shown later, with the type and actual position of the crop residue above the surface of the ground. In these experiments C varied from 0.8 to 1.8 and, in the units used, had an average value of 1.2.

The amount of stubble required to reduce the erosion to a negligible factor varied greatly with the relative erosiveness of the soil and the velocity of the wind. With the method used to apply the stubble to the surface of the soil, the amount required varied from nearly 0 for highly resistant to as much as 4 tons per acre for very highly erosive soils. This is an equivalent of nearly 0 to 2.5 tons per acre of residue retained above the surface of the ground. On highly resistant samples of Sceptre clay and Fox Valley silty clay loam, from one-eighth to one-half ton per acre was required to withstand a 22-m.p.h. wind as measured at 1 foot height. To withstand the same velocity of wind 0.5 to 1.5 tons per acre were required for moderately erosive samples of Haverhill loam, Cypress clay loam and Hatton fine sandy loam, and 1.5 to 4 tons per acre for very highly

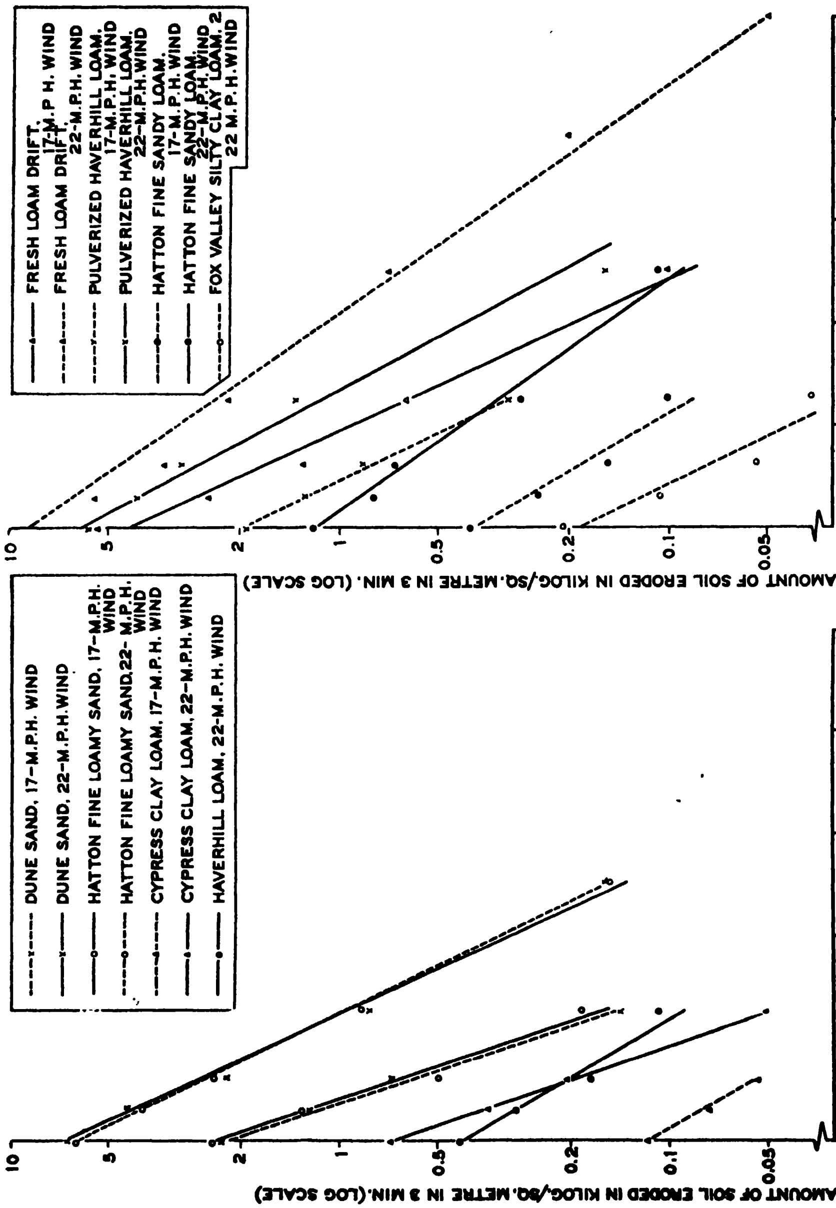

FIGURE 3. Relation between wind erosion and the amount of stubble above the ground.

erosive samples of pulverized Haverhill loam, Hatton fine loamy sand, fresh loam drift, and dune sand. Thus, the greater the erosiveness of the soil the greater was the quantity of stubble required for equal protection. The effectiveness of stubble in preventing erosion of any soil would, of course, depend not on the amount applied, but mainly on the amount retained above the surface of the ground. Figure 4 shows a heavy cover of combine stubble which gave complete protection to soil against highly

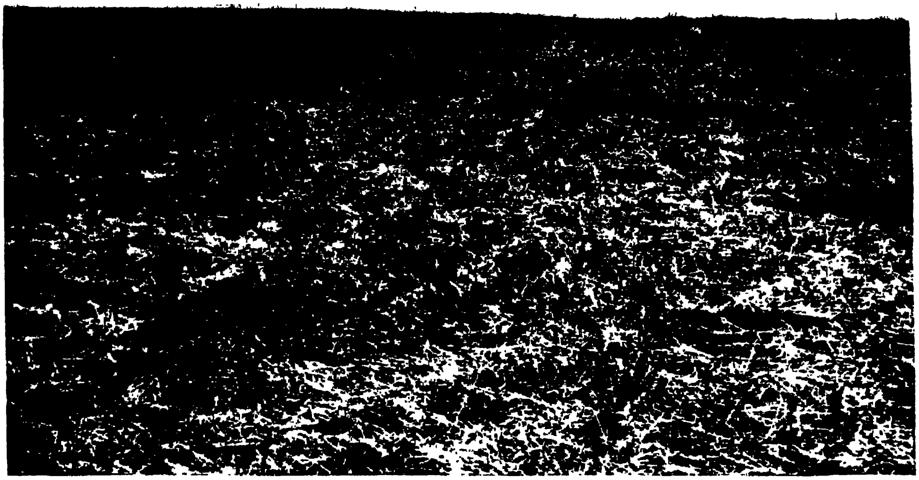

FIGURE 4. A heavy cover of wheat stubble and straw on a highly erosive Sceptre heavy clay affording virtually complete protection against wind.

erosive winds. In this case, with the proper use of a suitable surface tillage implement, approximately 1¾ tons of stubble per acre were retained above the surface of the ground.

The data further indicate that the higher the velocity of wind the greater was the amount of crop residue required. Thus, 0.5 ton per acre of stubble on Fox Valley silty clay loam under a 17-m.p.h. wind gave about the same degree of protection as 1 ton per acre under a 22-m.p.h. wind. Likewise 1 ton per acre on fresh loam drift under 17-m.p.h. was about as effective as 2 tons under a 22-m.p.h. wind. To give equal protection, therefore, the amount of stubble had to be approximately doubled to withstand the increase in wind velocity of 5 m.p.h. at 1-foot height.

TABLE 1.—THE EFFECT OF LENGTH OF WHEAT STUBBLE ON WIND EROSION

Length of stubble (inches)	Wind in m.p.h. at 12-inch height	Amount of soil in tons per acre eroded when stubble was applied at		
		0.25 ton/acre	0.5 ton/acre	1 ton/acre
2	17	22.6	10.9	3.3
6	17	13.3	6.0	2.7
2	22	84.0	61.4	22.8
6	22	64.7	53.4	13.9
2	27	228.0	170.0	145.0
6	27	174.0	156.0	95.7

Table 1 shows the relative effect of the length of stubble on wind erosion. Under wind velocities up to 27-m.p.h. the shorter stubble afforded less protection than equal amounts of longer stubble. The percentage difference was greatest under a moderately low velocity and least under a very high one. Thus, under a 17-m.p.h. wind the 2-inch stubble was, on the average, 64.5% as effective as the 6-inch stubble, but under a 22-m.p.h. wind it was 75.0% and under 27-m.p.h. 78.0% as effective as the longer stubble.

TABLE 2.—THE EFFECT OF DEGREE OF BURIAL OF WHEAT STUBBLE ON WIND EROSION

Amount of stubble and method of application	Amount of soil eroded in tons per acre			
	Hatton fine sandy loam		Fox Valley silty clay loam	
	17-m.p.h. wind	22-m.p.h. wind	17-m.p.h. wind	22-m.p.h. wind
None	0.70	3.18	0.48	1.59
0.25 ton, uniformly mixed with 2-inch depth of soil*	0.59	2.40	0.29	1.26
0.25 ton, anchored†	0.45	2.20	0.19	0.83

* Approximately one-half of the stubble remained above the ground surface.

† Eight-inch stubble was anchored by pushing it down to 2-inch depth at an angle of 45 degrees with the wind. Approximately five-eighths of the stubble was, therefore, above the ground surface.

The effect of degree of burial of wheat stubble is indicated in Table 2. The data show that mixing 8-inch long stubble into the 2-inch layer of surface soil was somewhat less effective than merely anchoring the stubble by pushing it down to 2-inch depth at an angle of 45 degrees with the wind. The former treatment is somewhat comparable to a condition that would be obtained with a disk harrow or a one-way disk, whereas the latter may be obtained with various types of subsurface blade implements. In the former treatment approximately one-half and in the latter approximately five-eighths of the stubble was above the surface of the ground. There was, therefore, about 20% less stubble above the ground surface in the former than the latter case. The average difference in the intensity of erosion between the two types of treatment amounted to approximately 20%.

Figure 5 gives further information on the effect of degree of burial of straw and stubble on wind erosion. In this experiment the stubble was 8 inches long, and straw was as it came from the threshing machine and of variable length ranging from a fraction of an inch to 12 inches. In one case the straw or stubble was merely scattered on the surface of the ground, in the other it was partially mixed with the surface soil. In the latter case about one-half of the residue was above the surface of the ground. The data show that under a 17-m.p.h. wind straw scattered on the surface of the ground was slightly more effective in overcoming drifting than when half of it was above and half below the ground surface. Under a 22-m.p.h. wind, on the other hand, most of the straw scattered on the surface of the ground was blown off by the wind, giving little protection to the soil.

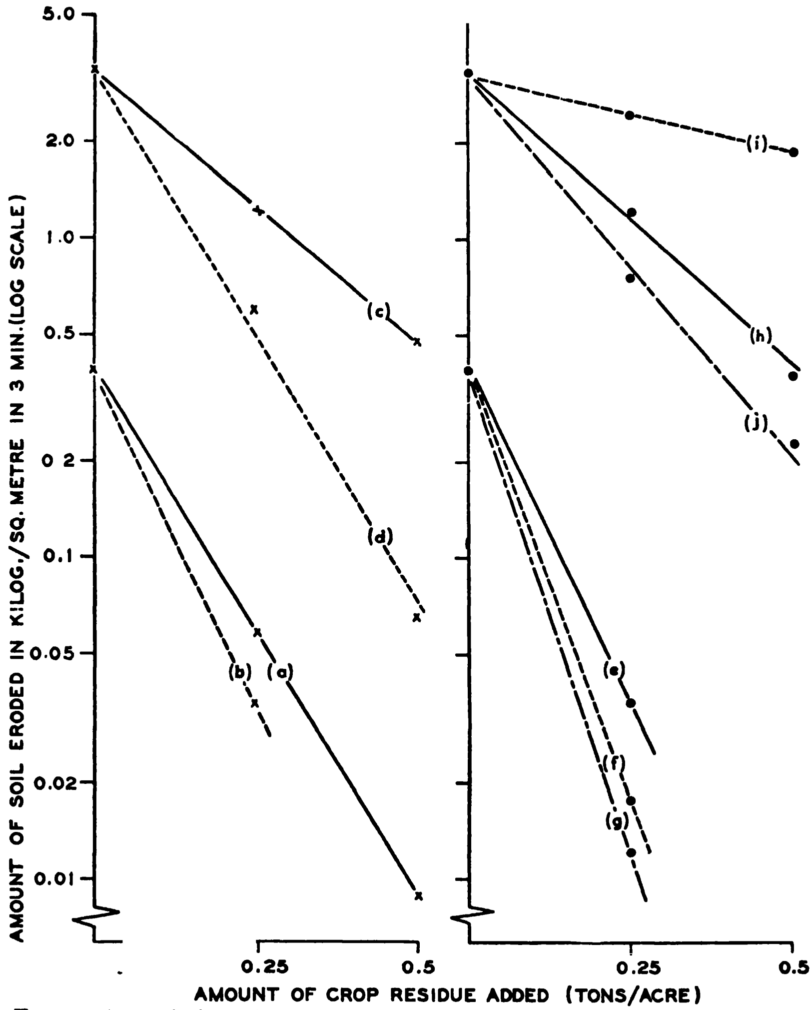

FIGURE 5. Relative effect of wheat stubble and straw on wind erosion; (a) stubble, (b) straw, partially worked into the ground, 17-m.p.h. wind; (c) stubble, (d) straw, partially worked into the ground, 22-m.p.h. wind; (e) stubble, (f) straw, (g) mixture of stubble and straw, scattered on the ground, 17-m.p.h. wind; (h) stubble, (i) straw, (j) mixture of straw and stubble, scattered on the ground, 22-m.p.h. wind.

The results with stubble were entirely different to those with straw. Because of the greater density of the crowns, the stubble was less subject to removal by wind. However, as a result of greater density, and because of the fact that up to as many as 5 culms were held together by a single crown, stubble had less protective surface and failed to cover the ground as thoroughly as an equal weight of straw. When anchored to the surface of the ground the straw was therefore much more effective in overcoming erosion, irrespective of wind velocity. When merely scattered on the surface of the ground, the straw was also more effective than stubble, but only under wind not sufficiently strong to carry much of it away. As soon as the wind reached a velocity of about 20 m.p.h. most of the straw moved off with the wind and left much of the soil surface unprotected. On the other hand, little stubble was moved by a 17-m.p.h. wind and only from one-third to one-half by a 22-m.p.h. wind.

Stubble scattered on the surface of the ground was somewhat more effective in controlling soil drifting than where one-half of it was buried in the ground. The difference was greater under a 17-m.p.h. than a 22-m.p.h. wind, due to the fact that the higher velocity caused greater removal of stubble not anchored to the ground.

When scattered on the surface of the ground, mixtures of equal quantities of straw and stubble were more effective in controlling soil drifting than straw or stubble alone. In these cases, the straw was the effective agent in protecting the soil against wind and the stubble in supplying sufficient anchorage to the straw.

DISCUSSION AND CONCLUSIONS

Results reported in this paper indicate that crop residue retained at the surface of the ground has a very marked effect in preventing wind erosion of soil.

Figure 1 shows that the velocity of wind near the ground was highest over a smooth, bare surface (curve a) and lowest over a ridged surface covered with straw (curve d) and that the amount of eroded soil was in direct proportion to wind velocity. However, the velocity over a level, straw covered surface (curve b) was higher than over a ridged, bare surface (curve c), yet the amount of eroded soil was in inverse order to wind velocity. It is evident that the effectiveness of the straw in preventing the erosion of the soil is not entirely due to the reduction in the surface velocity of the wind, but more particularly to the high capacity of the straw to trap the eroding soil. The effect of straw on the surface of the ground is apparently equivalent to changing the condition of the soil itself in such a way as to increase its resistance to wind erosion..

Information has been obtained to show that the intensity of wind erosion is reduced most markedly by the first increment of straw or stubble added to the soil surface, but additional amounts are proportionately less and less effective. This indicates that relatively small quantities of residue, not sufficient to prevent erosion completely, are valuable in greatly reducing the amount of damage that would otherwise occur (Figure 6).

The data show that on moderately to very highly erosive soils from 0.5 to 2.5 of wheat stubble distributed uniformly above the surface of the ground may be necessary to prevent serious damage from wind. The actual amount, of course, would depend somewhat on the length of stubble and degree of anchorage to the ground.

It is evident that the less erosive the soil, the smaller is the amount of stubble, or straw, required to control wind erosion. Hence, soil cloddiness, moisture content, and roughness of ground surface have an additive effect to vegetative litter in controlling wind erosion. The efficiency of a ploughless fallow method by which crop residues are retained at the surface of the ground is, of course, limited by the amount of residue available. In most of the semi-arid regions of the Canadian prairies good crop growth is by no means assured, and years may occur when insufficient amounts of residue may be available for adequate protection. The use of crop residues should therefore be made in combination with other well recognized control practices, particularly such as strip farming and the maintenance of cloddy and ridged soil conditions.

It is also recognized that the use of crop residues for both wind and water erosion control leaves many problems still unsolved, such as the

effect of relatively large quantities of organic residue on soil structure and fertility, and their relation to insect and plant disease control. Such problems are beyond the scope of this investigation and no attempt will be made to discuss them.

The question of maintaining a crop residue cover for wind erosion control is further complicated by the nature of the soil. Soils that do not retain a cloddy structure cannot, with any degree of safety, be left bare, and should therefore be covered with as much vegetative matter as can be conveniently handled by suitable tillage implements. Some medium textured soils, such as loams, on the other hand, can maintain a cloddy, wind resistant structure, particularly after deep ploughing. Ploughing would bury all the organic residue, but would have a definite advantage in overcoming erosion by wind when insufficient amounts of residue are present to give the soil the necessary protection. The question that must

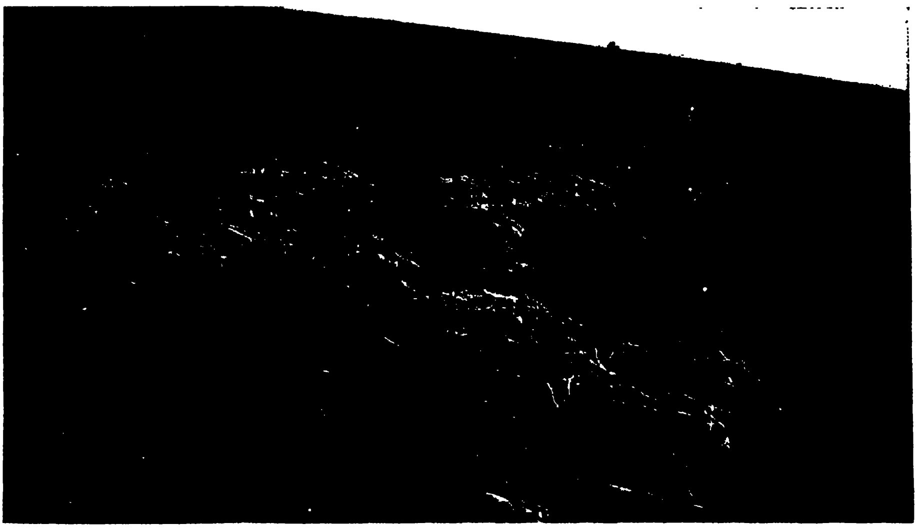

FIGURE 6. Fallow partially protected from wind by short binder stubble. Due to insufficient anchorage, much of the stubble is blown into heaps. Bare areas have 2 to 4 inches of top soil removed, whereas the protected areas show no removal or slight accumulation of eroded soil.

be answered is whether the influence of increased cloddiness produced by ploughing is greater than the protective value of crop residue that may be retained at the surface of the ground. This and previous investigations (2, 3) furnish some information on the relative effects of crop residue and degree of cloddiness on wind erosion of soil.

It is recognized, that dependence on a cloddy structure alone for wind erosion control is hazardous; hence a crop residue cover and a cloddy structure should be the ideal. A number of new tillage implements have been developed and applied recently with this ideal in mind.

The data indicate that under similar conditions of soil and wind 1 blade of 6-inch long stubble affords more protection to the soil surface than 3 blades of 2-inch long stubble. The reason for this phenomenon is not clear. It is perhaps due to the fact that blades of longer stubble extend

higher in the air than those of shorter stubble, thus causing greater reduction of wind velocity near the ground. In addition to greater protection from longer stubble, cutting the crop as high as possible would have an added advantage of increasing its total quantity, thereby offering still greater protection to the soil. This is particularly important where crops are harvested with a binder.

The type of crop residue and the degree to which it is buried in the soil are also of great importance. When stubble is buried, as with a plough, its protective value is eliminated. Various forms of blade implements have recently appeared on the market which are designed to destroy weeds and at the same time maintain crop residues on the surface of the ground. The information obtained from this study, however, indicates that scattering the crop residue on bare ground may not give as much protection against wind as if it is scattered on and anchored to the ground by partial mixing with the surface soil. This is especially true for light organic materials such as straw, but not for heavier materials such as stubble. Straw scattered among the stubble, as with a combine, affords an almost ideal type of cover for wind erosion control. In such cases the stubble provides the necessary anchorage to the ground, and the straw the more thorough protection to the surface.

SUMMARY

Results of wind tunnel experiments indicating the effect of wheat stubble and straw on the erosiveness of 16 widely different soils are outlined.

It was found that crop residue retained at the surface of the ground has a very marked effect in reducing wind velocity and erosion of the soil. It is shown that the effectiveness of organic residue in preventing wind erosion is partly due to the reduction in wind velocity, but more particularly to the high capacity of the residue to trap the eroding soil.

The amount of wheat stubble or straw required to prevent erosion varied greatly with the relative erosiveness of the soil and the velocity of the wind. For soils and velocities used, the amount varied from nearly 0 to 2.5 tons per acre of stubble retained above the surface of the ground.

The higher the velocity of wind, the greater was the amount of crop residue required. To give equal protection the amount of stubble had to be doubled to withstand an increase in velocity of 5 m.p.h. at 1-foot height.

Short stubble afforded less protection to the soil than an equal amount of longer stubble.

Stubble afforded less coverage to the ground than an equal weight of straw, but was less subject to removal by high winds. When scattered on the surface of the ground mixtures of straw and stubble afforded more protection against wind than equivalent amounts of straw or stubble alone.

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THE USE OF *DROSOPHILA MELANOGASTER* MEIG. FOR COMPARING THE TOXICITY OF STOMACH POISON DUSTS[1]

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The problem of the blueberry maggot, *Rhagoletis pomonella* (Walsh), became acute in Yarmouth County, N.S., several years ago, so that control work became imperative if the industry were to escape serious damage. A considerable amount of field work has been performed with both power and hand dusters, resulting in a fair degree of success. The habits of the blueberry maggot fly and the nature of its environment, however, make a direct comparison of poison treatments impossible in the field. It is also a difficult insect to handle in the laboratory. A technique was therefore devised by which preliminary tests of various insecticides could be carried on with the pomace fly, *Drosophila melanogaster* Meig., which offers many advantages as a laboratory insect. Some parallel tests were also run with blueberry and apple maggot adults, which, while not conclusive, indicated that their reactions to some of the common poisons were similar to those of the pomace fly. No claim, however, is made that any of the results obtained with *Drosophila* are necessarily applicable to the maggot flies.

METHODS EMPLOYED

The flies to be tested were confined in a lantern globe, where they were supplied with water from a wick and food from a section of honey-treated paper, which was previously treated with dust in the manner described below. Each day all the globes were examined, and the flies removed and the sex determined.

Method of Rearing Flies

Flies for these tests were reared on a mixture of mashed boiled potatoes and one Royal yeast cake in cloth-covered cages as described by Stultz (4), but with the modifications made by Lord (2).

The flies were aged in a cloth-covered cage until three days old, being fed meanwhile by means of a wad of absorbent cotton moistened with a 5% solution of honey. This was placed in a petri dish with a slight excess of honey solution in the bottom to maintain the moisture content of the cotton. During the morning of the third day the flies were placed in the lantern globes containing the materials to be tested.

Preparation of the Globe

The top of the lantern globe was covered with a piece of good quality cheesecloth (B, Figure 1), that had stapled in the centre a perforated square of light cardboard (b_1, Figure 1), which was stoppered with a cork after

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the globe had been charged with flies. When the treated microscope slide (D, Figure 1) described below had been fastened into place, the bottom of the globe was covered with a cloth (C, Figure 1) holding a strip of blotting paper, (c_1, Figure 1) $1\frac{1}{4}$ by 6 inches, stapled into a slit in the cloth and reinforced with two small strips of waxed cardboard (c_3, Figure 1). This cloth with the attached wick was then fastened to the bottom of the globe by means of a ring of thin brass wire and the prepared globe was then set into an 800 ml. beaker filled to within an inch of the brim with water. The wick served to supply moisture for the flies and food was obtained from the honey-treated slide.

The bottom cloth had been previously soaked in a gasoline solution of paraffin wax to prevent absorption of moisture from the wick into the cloth.

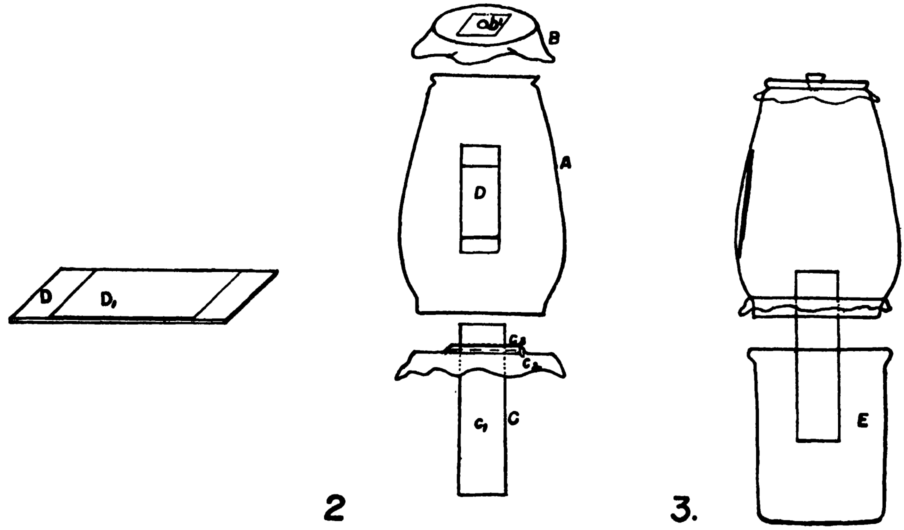

FIGURE 1.

Preparation of the Microscope Slide Bearing Food Material

Preparatory to making up the slides, white blotting paper was soaked in a 50% honey solution and then carefully dried, care being taken to keep the moisture evenly distributed while drying. A 50% solution of honey seemed to be about the maximum concentration that could be used and still ensure a non-sticky surface upon drying. This treated paper was then cut into rectangular strips 1 by 2 inches and glued to glass microscope slides. These were later coated with dust in a laboratory duster described by Payne and Stultz (3). A bell jar was used in place of the 4-sided chamber in this device, and in later experiments the whole device was discarded in favour of the more elaborate apparatus described by Heuberger and Turner (1), which is much better suited to the dusting of slides. The latter device also eliminates trouble from static electricity as well as allowing much greater control over the amount of dust deposited per slide. It is hoped that further investigation will reveal methods whereby the dosage per slide can be predetermined. The dusted slides have to be handled quite carefully to avoid jarring the dust loose while they are being attached to the walls of the lantern globe with strips of cellulose tape.

Method of Placing Samples of Flies in the Globes

In charging the globes it is necessary to take precautions to have representative samples of the fly population in each globe. The flies were collected into a gum jar, the top covered with a piece of cotton, and when they crowded to the light side they were easily dislodged into a heap in the bottom of the jar. The male flies seemed to be able to get out of the mêlée more readily than the females so it was necessary to dislodge the flies into a heap and quickly remove the desired sample with an aspirator. Usually three globes were used per material tested. To ensure an even distribution of the samples of flies, all the globes in a series of tests were charged at random. In this way the three globes in which any one material was being tested were never charged consecutively.

TESTS UPON THE TECHNIQUE EMPLOYED

The dead flies were removed each day, the sex determined and the results recorded. In removing the flies there is grave danger of the operator drawing up small amounts of poison from the bottom of the globe if a *mouth suction type of aspirator* is used. A certain amount of dust is dislodged by the flies in feeding upon the slides and although the amount of poison in the bottom of a globe is not great, the amount absorbed after removing the flies from 80 or more jars every day would probably reach formidable proportions.

Influence of the Kind of Food

Although previous experience with feeding *Drosophila* adults had revealed that they will live for a considerable length of time on either honey or cane sugar solution, a series of tests was initiated to determine which material was best suited. A number of filter papers (approximate area 6.4 square inches) were thoroughly soaked in solutions of the two materials and tested in the lantern globes.

In this case, where there was a large feeding surface and a small number of flies, it will be noted in Table 1 that the average length of life is much longer than it was in subsequent tests, where 2 square inches of paper was used with a larger number of flies. It is also very apparent that honey is a somewhat better food material than cane sugar.

TABLE 1.—INFLUENCE OF CONCENTRATION OF HONEY OR SUGAR ON THE LONGEVITY OF *D. melanogaster* ADULT*

Paper treated with	No. flies per globe	Average longevity in days	
		Male	Female
50% honey	47	36.7	39.4
50% sugar	60	31.5	34.3
25% honey	75	20.0	24.5
25% sugar	107	11.7	13.5
12.5% honey	73	6.7	9.8
12.5% sugar	83	2.2	3.5
6.2% honey	108	2.0	3.3
6.2% sugar	101	1.4	3.1

* Approximate area of filter papers 6·4 inches.

Influence of Amount of Feeding Surface per Fly

It is not possible with the present technique to place a predetermined number of flies in any globe, so 3 series of globes were charged with the aim of having too few flies, a sufficient number, and too many flies respectively. The globes also contained two concentrations of honey and two areas of treated paper. Duplicate globes were prepared in each case. The results are shown in Table 2.

TABLE 2.—INFLUENCE OF THE NUMBER OF FLIES PER GLOBE, CONCENTRATION OF HONEY AND AREA OF TREATED PAPER ON THE LONGEVITY OF *D. melanogaster* ADULTS

Concentration of honey	Area of treated paper	Flies per globe	Average longevity		Average	
			Male	Female	Male	Female
%	sq in.	no	days	days	days	days
50	2	50	20.4	21.5	20.9	22.1
50	2	48	21.6	22.3		
50	2	107	16.1	17.2	16.1	17.4
50	2	98	16.2	17.5		
50	2	197	11.2	12.3	11.8	12.8
50	2	154	12.6	13.4		
50	1	44	15.7	17.3	16.5	18.0
50	1	34	17.3	19.1		
50	1	107	12.4	13.0	10.7	12.3
50	1	77	8.4	11.2		
50	1	216	6.7	7.7	6.9	7.7
50	1	156	7.1	7.7		
25	2	48	9.6	11.0	9.5	10.9
25	2	50	9.5	10.7		
25	2	165	7.3	8.1	7.1	8.2
25	2	83	6.9	8.4		
25	2	208	6.5	7.2	6.1	7.0
25	2	221	5.6	6.8		
25	1	56	8.0	9.2	7.2	8.3
25	1	50	6.4	7.2		
25	1	114	7.0	7.8	6.3	7.1
25	1	81	5.3	6.2		
25	1	237	5.7	6.7	4.9	5.9
25	1	183	3.9	4.9		

It is apparent that the number of flies per globe, the concentration of honey, and the amount of treated surface all have an important bearing on the results. The figures are quite uniform but in all cases the average is somewhat lower than has been the experience in other tests.

Influence of Age of the Prepared Slides

As there are a number of operations involved, each time-consuming, in preparing a series of tests, it is often necessary to make the slides up

1 to several days before the tests are started. It was therefore important to know if any change took place in the food value of the prepared slides. A number of slides were prepared from time to time and stored in a dry closet and then all slides were tested at the same time. Two square inches of honey-treated paper was used.

The slides do not deteriorate greatly with age, as is shown in Table 3. Those made up during the few days prior to testing seemed to result in somewhat greater longevity of the caged flies but these differences are slight and do not seem to be significant.

TABLE 3.—INFLUENCE OF THE AGE OF THE SLIDES ON THE LONGEVITY OF *D. melanogaster* ADULTS IN LANTERN GLOBES

Age of prepared slide	Globes tested	Total flies used	Average longevity	
			Male	Female
days	no.	no.	days	days
68	3	243	23.1	29.4
29	3	244	21.0	25.5
23	3	303	25.6	27.9
18	3	289	22.5	26.9
10	3	288	27.7	29.5
5	3	349	23.0	24.9
4	3	253	25.5	25.6
3	3	301	26.7	30.1
2	3	278	28.2	29.2
1	3	279	28.6	29.8
Day of test	3	262	29.7	31.4

Influence of Dust Film on the Slide

The diluent used in a dust may possibly form a mechanical barrier to prevent the flies from obtaining sufficient food, so this point was examined experimentally by dusting slides, treated with 25% honey solution, with supposedly inert materials. The results are shown in Table 4.

TABLE 4.—INFLUENCE OF MATERIALS USED IN DUST MIXTURES ON THE LONGEVITY OF *D. melanogaster* ADULTS IN LANTERN GLOBES

Material	Flies per globe	Average longevity		Average	
		Male	Female	Male	Female
	no.	days	days	days	days
Talc	117	13.4	14.7		
Talc	92	15.5	16.7	13.9	15.0
Talc†	121	13.0	14.0		
Walnut shell flour	118	13.3	14.4		
Walnut shell flour	106	13.2	14.6	13.3	15.0
*Walnut shell flour†	132	13.0	14.1		
*Walnut shell flour†	123	14.4	16.5		
Check	85	17.2	18.4	15.0	16.1
*Check†	122	13.4	14.2		

* Two square inches of filter paper treated with 25% honey solution.
† Slide dipped in water and excess quickly shaken off just before dusting.

The influence of the dust film did not seem to be a very important factor but the results were not conclusive.

RESULTS OF SOME TOXICITY TESTS

A considerable number of materials were tested by the methods described above and some typical results with some common poisons are given. The results in Table 5 are from slides which were dusted in the Payne and Stultz (3) duster. Those in Table 6 are from slides treated in the Heuberger and Turner (1) duster.

TABLE 5.—LONGEVITY OF *D. melanogaster* ADULTS WITH SLIDES DUSTED IN PAYNE AND STULTZ (3) APPARATUS*

Material	Globes	Total flies	Average longevity	
			Male	Female
	no.	no.	days	days
Lead arsenate alone	3	191	6.7	7.5
Lead arsenate—hydrated lime	3	266	8.1	8.9
Lead arsenate—gypsum	3	235	6.3	6.8
Lead arsenate—sulphur	3	300	7.7	8.1
Lead arsenate—talc	3	215	6.6	7.5
Lead arsenate—walnut shell flour	3	308	6.9	7.8
Lead arsenate—calcium arsenate	3	235	4.9	5.8
Calcium arsenate alone	3	284	3.4	4.3
Calcium arsenate—hydrated lime	3	317	4.4	5.3
Calcium arsenate—gypsum	3	266	3.7	4.6
Calcium arsenate—sulphur	3	307	3.4	4.3
Calcium arsenate—talc	3	262	3.4	4.4
Calcium arsenate—walnut shell flour	3	280	3.4	4.2
Synthetic cryolite alone	3	207	5.8	6.1
Synthetic cryolite—hydrated lime	3	262	9.9	10.6
Synthetic cryolite—gypsum	3	260	4.7	4.7
Synthetic cryolite—sulphur	3	295	6.5	7.7
Synthetic cryolite—talc	3	271	6.3	7.4
Synthetic cryolite—walnut shell flour	3	298	6.3	8.7
Sulphur alone	3	406	17.9	18.1
Check	3	239	23.3	27.3

* Amount per charge, 0.5 gm. of mixtures; .025 gm. of undiluted poisons. All mixtures 50 : 50.

The diluents used seemed to have little influence on the speed of toxic action except in the case of gypsum which appeared to have a slight adjuvantal value with both lead arsenate and cryolite. With synthetic cryolite as a dust, hydrated lime seemed to have a very deleterious effect.

Increasing the copper sulphate content of the copper sulphate-lime series appeared to have little or no influence in decreasing the longevity of the caged flies. With the copper sulphate-lime-calcium arsenate series variation in the deposit of dust seemed to be more closely related to the differences in longevity than did the amount of copper sulphate used in the mixtures. It did not appear that copper-lime dust as a diluent had much influence on the toxicity of calcium arsenate.

TABLE 6.—LONGEVITY OF *D. melanogaster* ADULTS WITH SLIDES DUSTED IN HEUBERGER AND TURNER (1) APPARATUS

Proportions of materials	Deposit dust per slide	Probable deposit cal. arsenate	Flies used	Average longevity	
				Male	Female
	gm.	gm.	no.	days	days
Copper sulphate–calcium arsenate–hydrated lime†					
5–30–65	.0023	.0007	228	7.9	10.8
10–30–60	.0041	.0012	254	7.1	9.0
15–30–55	.0038	.0011	278	7.1	9.1
20–30–50	.0030	.0009	311	6.8	8.5
25–30–45	.0026	.0008	332	7.2	9.1
Copper sulphate–hydrated lime†					
5–95	.0026		196	24.4	26.2
10–90	.0043		275	21.9	24.5
15–85	.0059		250	16.3	19.0
20–80	.0067		218	16.1	18.7
25–75	.0065		282	15.0	17.6
Calcium arsenate	.0017		341	5.6	7.3

* Amount per charge, 0.5 gm. dust. Dust settling for first 30 seconds discarded. Slides exposed during next 5 minutes.

† Monohydrated copper sulphate.

SUGGESTIONS FOR IMPROVEMENT IN THE METHODS DESCRIBED

There are several important factors which need investigation, the results of which may necessitate some fundamental changes in the methods described:

1. It is important to know more about the influence of the amount of poison per slide on the longevity of the flies.

2. Methods for placing a predetermined dosage of dust on the slides should be worked out.

3. When the above points have been investigated, series of tests should be run in which the poisoned slides are removed and replaced by unpoisoned slides after any desired interval of feeding.

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CONTROL OF WATER-CORE OF TURNIPS BY SPRAYING WITH BORAX[1]

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The table turnip (rutabaga) is an important cash crop in western Ontario. More than 2 million bushels of the 1942 yield were shipped to the United States market, alone.

Water-core or Brown Heart is one of the most troublesome diseases with which the growers must contend. This physiological disorder is caused by a deficiency of boron, and its presence renders the turnip unsaleable for table use. The extent of water-core in the various turnip districts varies from year to year but the loss from this disease, for other than stock feed, has been estimated as high as 20% in some years. The recommendations for soil application of borax to control this disorder have not been generally adopted; too many failures have been met. In one experiment at the Ontario Agricultural College, borax was applied to the soil in amounts sufficient to be toxic to certain succeeding crops (100 lb. per acre) and yet no control of water-core was obtained. The high lime content of the soil is a likely contributory agent to failures of soil applications of borax to control the disease.

The investigations herein reported gave evidence that the required amounts of boron can be applied, in a practical manner, to the turnip plant, by spraying the leaves with an aqueous solution of borax. An abstract of the earlier phases of this investigation has already been published (1).

INVESTIGATIONS

Experimental

An extensive series of small plot experiments were carried on during 1940 and 1941 to determine if foliage spraying with borax would control water-core. From these experiments a promising spray schedule was obtained. It was found that a 2% aqueous solution of borax (approximately saturation in cold water) could be used without causing foliage burning; that spraying the upper surfaces of the leaves was adequate but the inclusion of a spreader was necessary; and that two sprays would prevent water-core, the first when the roots were 1 to 2 inches in diameter, the second, approximately 1 month later.

In 1942, spraying for the control of water-core was tested in 12 turnip fields in the neighbourhood of Guelph, Ontario. These fields were on farms where water-core had been severe the previous year. Plots, 6 rows wide and about 75 ft. long, were established in 11 of these fields. A 5-gallon knap-sack sprayer was used to apply a 2% borax solution with ¼% liquid Orvus (Procter and Gamble, Toronto) added as a spreader. Just

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prior to the time of harvesting, 5 samples, each of 10 consecutive turnips in a row, were cut from the unsprayed portions of the field immediately bordering the 4 sides of each sprayed plot. If a significant amount of water-core was present, then 5 similar samples were cut from various areas within the sprayed plot. Of the 11 fields in which spraying was done in this manner, 5 contained sufficient water-core in the checks to give an index of the control obtained by spraying. The remaining field, consisting of about 2 acres of turnips, was completely sprayed with the exception of interspersed checks of 3 rows each. A 40-gallon 4-row potato sprayer with 1 nozzle per row turned down on the foliage was used in this instance. Water-core was prevalent in the checks at the time of harvesting and 10 samples, similar to those described above, were cut from various portions of sprayed and unsprayed rows, respectively.

TABLE 1.—THE CONTROL OF WATER-CORE OF TURNIPS OBTAINED BY SPRAYING THE LEAVES WITH BORAX

Field	Soil type and turnip variety	Root diameter		Turnip quality at time of harvesting	Water-core incidence					
					Unsprayed areas			Sprayed plots		
		1st spray	2nd spray		None[1]	Mild[2]	Severe[3]	None	Mild	Severe
		in.	in.		%	%	%	%	%	%
A	Clay loam Purple King	1-1½	4-6	Black rot and soft rot prevalent	70	14	16	100	0	0
B	Sandy loam Purple King	1	2-5	Very large, rough; stock feed only	54	6	40	100	0	0
C	Sandy loam Laurentian	1-2	4-5	Grade A	38	18	44	98	2	0
D	Sandy loam Canadian Gem	1	2-4	Grade A	18	8	74	98	2	0
E	Light sandy loam Laurentian	2-3	—	Stunted, woody	6	32	62	96	4	0
F	Sandy clay loam Laurentian	1-1½	2-4	Grade A	25	20	55	100	0	0

1. None—no water-core present.
2. Mild—minor indications of water-core but still saleable.
3. Severe—unsaleable because of water-core.

Information concerning the 6 fields in which significant amounts of water-core occurred in the checks is presented in Table 1. Sample portions of fields A to E were sprayed with the knap-sack sprayer while field F was sprayed with the 4-row potato sprayer. As may be seen from this table, practically complete control of water-core was obtained regardless of severity of water-core in the checks. Moreover, the soil type, turnip variety, and turnip quality at the time of harvesting did not influence the degree of control obtained. In one instance (field E) control was obtained with a single spray, applied at a stage of turnip development approximately intermediate between that of the 2-spray schedule on the other fields. The control obtained on field F indicated that the 4-row potato sprayer was a satisfactory means of application.

Commercial Application

A considerable acreage of turnips was sprayed on a commercial basis, during 1943, throughout widely scattered districts of western Ontario. Records were obtained from 42 farms involving about 250 acres of turnips. The following spray formula was used: Borax 2% (8 lb. to 40 gal. of water) or saturation in cold water where the farmer mixed the spray in a separate barrel and always kept some undissolved borax in the bottom of the barrel after each refill; bentonite clay, 2 lb. to 40 gal. of water, as a sticker; and liquid Orvus, ½ pint to 40 gal. of water, which was usually decreased in amount in successive spray-tank loads because the Orvus tended to accumulate as froth in the tank. In all instances the upper surfaces only of the leaves were sprayed. In most cases a 40-gallon, 4-row, potato sprayer with 1 nozzle per row was used. However, some used large orchard sprayers with either a gun or boom attachment while others improvised sprayers of devious kinds. The most efficient equipment observed was that of a tractor with a spray tank mounted on a platform over the rear axle and a 4-row boom attached behind the front wheels. No appreciable damage to the turnip foliage was caused by any of the spray equipment; a rubber-tired tractor caused the least damage.

The spray schedule on different farms varied somewhat owing in part to the limited amount of spray equipment and to labour shortage. Some applied the first spray when the roots were 1 to 2 inches in diameter but did not apply the second spray 1 month later. Others attempted to reduce the schedule to 1 application by spraying when the roots were 2 to 4 inches in diameter; this was suggested by the control obtained in one field during 1942 (See Table 1, field F).

The variation in spray schedules provided useful information with respect to future recommendations. In several instances, where the spray was not applied until the roots were 2 to 4 inches in diameter, a few of the larger turnips developed water-core. In 2 fields the spray was applied after water-core was already present and no control whatever was obtained. It is important, then, that the spray be applied a considerable length of time prior to the normal inception of water-core. Practically complete control was obtained in all instances where the initial spray was applied before the largest turnips had reached a diameter of 2 inches.

Many of the growers who sprayed before the roots had reached a diameter of 2 inches obtained complete control of water-core with a single application. That a second application of spray (approximately 1 month later) is sometimes necessary was illustrated on one farm where the turnips have always been severely affected by water-core. Adequate checks were left in a 4-acre field on this farm when the initial spray was applied. One month later these checks showed more than 50% water-core while none could be found in the sprayed areas. A second spray was applied leaving a small portion of the field with only the initial spray. At the time of harvesting almost 100% of the turnips in the unsprayed checks were affected by water-core, more than 50% of the turnips in that portion of the

field which received only the initial spray were affected by water-core, while the remainder of the field which received the 2 sprays was completely free of water-core.

In one field considerable water-core developed in a few rows which were sprayed just as it was beginning to rain; the rest of this field was free of water-core. Therefore, the spray should have an opportunity to dry on the leaves prior to a rain.

In spite of the variation which occurred in the spray schedule, the control of water-core obtained was, on the whole, outstanding. It was difficult to obtain quantitative data on the effectiveness of the spray because many farmers left either inadequate, or else no checks at all. However, on 7 farms involving 46 acres of turnips adequate checks were left and these contained such a high percentage of water-core that it was obvious the entire fields would have been condemned had they not been sprayed. In these 7 instances, practically complete control was obtained by spraying. In no instance did any appreciable amount of water-core develop where the spray was applied in the proper manner and at the proper times.

CONCLUSIONS AND RECOMMENDATIONS

Spraying the leaves of turnips with a solution of borax will supply sufficient boron to the plants to give practical control of water-core. The cost of materials is less than $1.00 per acre, per spray, which is a cheap rate of insurance in those areas where soil applications of borax fail to give results. Spraying is simplified by the fact that it is not necessary to spray the under sides of the leaves. Any type of spraying machine can be used so long as a uniform coverage of the upper surfaces of the leaves is obtained. No appreciable mechanical injury to the leaves occurred from the wheels of a 4-row potato sprayer or a commercial orchard sprayer whether drawn by horse or by tractor.

Further investigations will be carried on during the coming season with respect to the use of various stickers and spreaders as well as the possibility of using a borax dust rather than an aqueous spray. In the meantime the following spray program is submitted as an effective and practical means to control water-core of turnips:

Dissolve borax at the rate of 8 lb. to 40 gal. of water or else use a saturated solution of borax in cold water. To this add bentonite clay at the rate of 2 lb. to 40 gal. of borax solution. If the bentonite clay is soaked in water over night at the rate of 1 lb. of clay to a pail of water it will mix more readily. Screen this mixture into the spray tank, add ½ pint of liquid Orvus and stir gently. The amount of Orvus may be decreased somewhat in succeeding tankfuls because it tends to accumulate as froth in the tank. Forty gallons of spray is sufficient for an acre of turnips.

The first spray should be applied when the roots are 1 to 1½ inches in diameter but not more than 2 inches in diameter. This one spray is sufficient to prevent a mild to moderate occurrence of water-core but not always for a severe occurrence. Since it is impossible to predict the severity to which water-core will develop, 1 or 2 check blocks should be

left in each acre of turnips preferably on or over the face of a knoll, or where water-core is most liable to be severe. A check block 8 rows wide and about 25 ft. long is adequate to allow for wind drift of the spray. If no water-core has developed in these check blocks a month after the first spray, the chances are that the second spray is not necessary. If, however, water-core is present in these checks, a second spray should be applied.

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FLOUR, A SUBSTITUTE FOR BRAN IN GRASSHOPPER BAIT[1]

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One of the most outstanding of the developments contributing to the progress of grasshopper control in North America has been the steady cheapening of the unit cost of poisoned bait without lessening its efficiency. In 1920, using the Kansas formula with bran the sole carrier and with citrus fruits and molasses as attrahents, the aggregate cost of material plus freight in Saskatchewan averaged $90.00 per ton (dry weight). In contrast, the bait used in that province since 1938 has averaged only $11.00 per ton, and yet is equally efficient under the majority of conditions encountered. This greatly reduced rate of cost has been fundamental to the enormous growth of grasshopper baiting campaigns.

To this development, Saskatchewan has made a considerable contribution. It is the purpose of this paper to outline the steps taken in this province and the work on which the decisions were based.

In the modification of bait formulae in Saskatchewan (Vigor (5, 6, 7)), four major stages are recognizable. In 1921 the carrier was changed from all bran to equal volumes of bran and sawdust. From 1921 to 1923, attrahents were gradually modified and eventually eliminated. In 1932 Saskatchewan pioneered in the adoption, for the entire campaign, of liquid sodium arsenite as the poison in place of powdered white arsenic. In 1938 flour as a substitute for bran in an extensive campaign was used first in this province. The flour-sawdust carrier has been used for all subsequent Saskatchewan campaigns, and has also been adopted elsewhere.

PRELIMINARY WORK OF 1934-37

The first specific attention by the present writers to the use of bran substitutes in grasshopper baits was given in 1934. Then, as a result of the impending bran shortage and the prospects of bran prices increasing, experimental work was undertaken in co-operation with the Saskatchewan Department of Agriculture. The purpose of the study was to examine all likely bran substitutes with a view to producing an effective bait at a lower cost. This involved consideration of the efficiency of the materials, their general and local supply, availability and market price, as well as whether they could be employed with the standard mixing station equipment or would require special processing such as passing through a hammer-mill. At that time the following materials were investigated: No. 4 Northern Hard red spring wheat, both coarsely and finely chopped; No. 1 wheat, coarsely and finely chopped; rolled wheat; "Blackhawk," a commercial preparation resembling finely chopped oats; oat hulls; oat chop; rolled

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oats; barley chop; alfalfa meal; ground flax; peat moss, one-quarter inch mull; horse manure (Criddle's mixture formula); and shorts; together with the following materials which were put through a hammer-mill: wheat straw, oat straw, alfalfa, sweet clover and wild slough hay. Seasoned and fresh sawdusts, both unscreened and finely screened, were also compared. The mixing, absorptive, and spreading qualities of numerous formulae were tested.

The most promising bran substitute indicated by this preliminary work was ground wheat, particularly low grade wheat. This was cheap, widely distributed and in ample supply. The formula of 25% ground wheat and 75% sawdust by bulk absorbed as much or slightly more water than the "standard" bait of 50% bran and 50% sawdust.[4] At the above proportion coarsely ground milled wheat spread well, but finely ground wheat tended to "ball up."

Cage tests with early instars of *Melanoplus mexicanus mexicanus* (Sauss.), *Camnula pellucida* (Scudder) and *Melanoplus bivittatus* (Say) indicated that bait with coarsely ground wheat at the proportions of 1 : 3 of sawdust by volume was just as efficient as the standard, each averaging 87.5% kill in four series (mean difference—nil, standard error 7.0). The two series with finely ground wheat produced results that did not differ statistically from the standard bait (mean difference 15%, standard error 21.4). In these preliminary cage tests, neither the age nor the texture of the sawdust appeared materially to affect its efficiency. The peat moss bait of equal volumes of moss and sawdust, although very absorbent and in efficiency equal to the standard bait in the single series tested, had several undesirable features. The peat moss was very dusty when dry and thus unpleasant to work with. It would absorb so much water that, unless great care was taken in mixing, the water would run off excessively when the bait was piled or bagged. In carload lots, moss and bran were about equal in cost.

Following the preliminary investigations of 1934 on bran substitutes, no experiments were conducted until 1938, as it had proved possible to secure sufficient bran at a reasonable price for the provincial control campaigns. During the interim, however, there were a few opportunities to observe the effectiveness of milled or ground wheat and of shorts.

DEVELOPMENTS OF 1938

After the extremely severe drouth of 1937, when no crops were harvested over a large portion of the prairie area of Saskatchewan, bran was so scarce that immediate search for a bran substitute was urgent. Commencing in March 1938 further investigations were started by testing the mixing qualities and water holding capacities of the more promising bran substitutes, including milled wheat, flour, ground screenings, and ground

[4]Throughout the experiments reported in this paper bran and sawdust in equal volume has been used as the standard carrier for checking the comparisons. In all baits, both in investigations and in campaigns, the poison used was liquid sodium arsenite, 8 pounds of As_2O_3 per gallon, used at the rate of 1 quart of poison solution to 100 pounds of bran or equivalent volume of carrier.

millet. On the basis of these and previous experimental data and field observations in Saskatchewan, together with parallel investigations conducted by Dr. J. R. Parker and his staff in the United States Bureau of Entomology and Plant Quarantine, this Laboratory recommended to the Saskatchewan Department of Agriculture that bran be replaced by ground or milled wheat, with all parts retained, or by low grade flour at the ratio of 1 part to approximately 13 parts of sawdust by volume. In practical terms this was stated as 3 gallons to 40 gallons, a volume which was suitable for the standard mixing machines; or, in large quantities at the proportion of 1½ to 2 tons of flour for each carload of sawdust. At this stage wheat was recommended in preference to flour. The low grade wheat, particularly durum wheat, was cheaper than low grade flour, and offered fewer difficulties when mixed by inexperienced operators. With improved mixing technique and the heavy demands for bait in June, flour largely replaced the wheat. However, all field control officers who had experience with both the ground wheat and flour preferred the former because of the better mixing and spreading qualities resulting from its high proportion of bran. Nevertheless, with flour as well as with ground wheat very satisfactory kills were reported by farmers and field control officers alike. This seems especially significant since there were none of the popular complaints of ineffectiveness that so often come with any new bait, especially one known to be cheaper.

Immediately after grasshopper hatching commenced in 1938, bait experiments on field plots were begun at Radisson, Saskatchewan, with the following baits: standard bait, low grade flour and sawdust 1 : 9; finely ground No. 3 durum wheat and sawdust 1 : 13; and apple peelings—sawdust 1 : 3. These baits were prepared and spread by hand on half-acre plots. Both the spreading of the bait and the collecting of grasshoppers were alternated between the two investigators V. L. Berg and W. B. Fox, to minimize the personal element. The spreading was done at the rate of approximately 10 lb. of bait (dry weight) per acre. Three hours after spreading, three cages, each containing approximately 100 grasshoppers, were collected from each baited plot and an unbaited area. Each day the hoppers were fed fresh vegetation and after 72 hours the mortality was determined. The net mortality, i.e. corrected for natural mortality which occurred among unbaited grasshoppers was then calculated; (the collections reported in Tables 1, 2 and 3 averaged 57%, 52% and 54% dead, respectively). The cages were 5½ inches square by 12 inches high with a wooden base and top, the latter having a 3½-inch hole fitted with cover; the sides were of galvanized wire screen, 14 mesh to the inch. This type, which was adopted from the United States Department of Agriculture, proved satisfactory and has been used throughout our work.

The 1938 results from 6 series of field tests with *Melanoplus mexicanus* and *Camnula pellucida* nymphs and adults are shown in Table 1. These experiments confirmed the general appraisal of bran substitutes throughout the campaign, namely, that milled or ground wheat and low grade flour produced mortalities which did not differ statistically from those of the standard bait.

TABLE 1.—STATISTICAL ANALYSIS OF 1938 BRAN SUBSTITUTE BAIT TESTS

Bait	No. cages	Mean diff.	Standard error	*t* Value
		%		
Apple vs. standard	18	18.2	6.25	2.917*
Low grade flour vs. milled wheat	18	3.8	1.90	2.000
Standard vs. milled wheat	18	5.9	3.18	1.853
Standard vs. low grade flour	18	2.4	4.43	0.534

* Statistically significant, i.e. 5% point.
(Baits which produced the higher average mortality are placed first in each pair.)

It will be noted that apple peeling bait 1 : 3 was significantly better than the others in 1938. However, this was not the case in 1939 (Table 2) when the proportion was 1 : 9. No further work was done with apple peelings because of their cost and inadequate volume of supply.

FURTHER FIELD EXPERIMENTS, 1939-40

Further experiments with bran substitutes were conducted in 1939 and 1940, in co-operation with the Dominion Entomological Laboratory, Brandon, Manitoba. The 1939 experiments were carried out at Lyleton, Manitoba, by H. W. Moore and W. B. Fox, and in 1940 at Eastend, Sask., by R. H. Handford, L. G. Putnam and D. S. Smith. The statistical analysis of the 1939 data is summarized in Table 2, and the 1940 data in Table 3. In the 1939 and 1940 experiments both the milled wheat and the low grade flour were used in the proportions 1 : 13.

TABLE 2.—STATISTICAL ANALYSIS OF 1939 BRAN SUBSTITUTE BAIT TESTS

Bait	No. cages	Mean diff.	Standard error	*t* Value
		%		
Analysis of aggregate data on *M. mexicanus* and *C. pellucida*				
Milled wheat vs. low grade flour	24	6.2	2.66	2.351*
Standard vs. low grade flour	24	4.5	2.47	1.839
Standard vs. apple	24	2.3	1.44	1.614
Milled wheat vs. standard	24	1.7	2.12	0.806
Analysis of *M. mexicanus* data				
Standard vs. apple	12	4.5	2.30	1.959
Standard vs. low grade flour	12	3.1	3.08	1.000
Standard vs. milled wheat	12	2.8	2.88	0.981
Milled wheat vs. low grade flour	12	0.2	3.08	0.081
Analysis of *C. pellucida* data				
Milled wheat vs. low grade flour	12	12.2	3.67	3.337†
Milled wheat vs. standard	12	6.2	2.60	2.409*
Standard vs. low grade flour	12	6.0	3.95	1.520
Standard vs. apple	12	0.2	1.62	0.105

* Statistically significant. † Highly significant.
(Baits with the higher average percentage kills are placed first in each pair.)

From the analysis in Table 2, based on 4 series of tests with each species, it is evident that the bran substitutes gave kills which did not differ statistically from the standard bait; except that with *Camnula pellucida* the milled wheat was superior to the standard. When the milled wheat bait was compared with the baiting containing low grade flour, however, the milled wheat bait was superior both in the tests on *C. pellucida* and in the aggregate data.

In view of the rather conclusive data from the previous experiments and campaigns the flour-sawdust bait was given only relatively minor attention in the 1940 experimental bait program. The data (Table 3), though limited and restricted to *M. mexicanus*, confirm the previous findings. Further confirmation is provided in the co-operative experiments of 1941 and 1942, not here reported (Handford (1), Handford and Putnam (2)), as well as in the campaigns of those years.

TABLE 3.—STATISTICAL ANALYSIS OF 1940 BRAN SUBSTITUTE BAIT TESTS

Baits	No. cages	Mean diff.	Standard error	*t* Value
		%		
Milled wheat vs. standard	6	6.0	7.32	0.820
Standard vs. low grade flour	9	1.4	3.66	0.393
Milled wheat vs. low grade flour	3	1.0	14.16	0.001

(Baits which produced the higher average mortality are placed first in each pair.)

MIXING TECHNIQUE

In preparing a grasshopper bait with flour and sawdust, somewhat greater care is required than with the bran mixture. Experience has shown, however, that with practice the flour-sawdust bait can be prepared both easily and quickly. The points to be watched are: uniform mixing and securing the correct proportion of liquid in each batch. If the flour and sawdust are dumped together into the mixer, the bait tends to ball up badly, especially when the sawdust is already quite wet. From such uneven mixes poor kills may result. No difficulty is encountered however, if the sawdust is put in first and the flour then sprinkled in from end to end with the machine in operation. This does not involve any material increase in time to prepare each mix. There may be wide variations in the absorptive capacity of sawdusts, i.e., seasoned vs. fresh sawdust, as well as in the actual moisture content of the sawdust prior to mixing. Therefore, the correct amount of water to be added must be determined by the mixing station operator for each new shipment of sawdust.[5] The strength of the poison solution must be similarly adjusted according to the water holding capacity of the carrier, since the liquid poison and water are combined for each batch before adding to the mix. If excess water is added it will run off, carrying with it some of the flour and poison; besides weakening the bait this run-off is a hazard to livestock. On the other

[5] Under experimental conditions, thoroughly dried sawdust had to be slightly moistened before adding the flour to prevent the flour from sifting through to the bottom of the mixer. However, this has never been a problem in mixing stations.

hand it is important that the bait be given all the moisture it will absorb, especially since the absorptive power of sawdust is smaller and slower than that of bran. The quantity of water can be safely increased if the bait is allowed to stand for some hours and undue pressure is avoided either in bagging or piling.

SAVINGS

Even before bran substitutes were in general use, the mere knowledge that satisfactory experimental results had been secured is authentically reported to have kept down the market price of bran. According to one of the shrewdest and most experienced field men, this saved the province $3.00 per ton on bran in 1934. On that basis the saving for that year alone was $44,000.

In 1938, the use of ground and milled wheat and of low grade flour instead of bran resulted in a saving of at least $40,000, according to calculations supplied by S. H. Vigor, in charge of purchasing supplies for the grasshopper campaigns. The latter figure is based only upon the prevailing price of bran. Had substitutes not been used, it is certain, considering the very scanty supply, that the price of bran would have advanced materially. It seems evident, therefore, that the real savings were considerably in excess of that figure.

The relationships are best revealed by comparing actual bait-material costs exclusive of transportation, as the latter varies with location of outbreak. In the three years preceding the introduction of flour, 1935 to 1937, inclusive, the average was $14.50 per ton (dry weight). From 1939 to 1942, when flour was used exclusively, the average was $7.40 per ton which was only 51% of the previous cost. This marked reduction in cost was due almost entirely to the change in bait formula rather than to variations in the unit cost of materials in different years (Table 5).

The cost of transportation, however, is also an important consideration. The greater the proportion of sawdust in the bait the more important becomes the freight costs for this item, especially when the source of supply is far from the grasshopper infested area. The effect of this on the relative costs of the two types of bait is illustrated in Table 4 by comparing two districts in which extensive campaigns have been necessary. Robsart represents the maximum sawdust haul (575 miles) and Rosthern one of the shortest (175 miles) in this province. For this comparison, the calculations are on the assumption that the campaign was conducted exclusively in either one or the other district. In 1939 the figure for bait tonnage used in the entire province was employed, while for 1940 the calculations are for the materials actually used in the general Robsart area which had the most severe grasshopper outbreak ever recorded in Saskatchewan. The actual saving in 1939 was approximately $88,000.

These calculations show that, including transportation as well as materials, the total costs for the flour-sawdust bait were only 51% to 65% of the costs which would have been incurred had the bran-sawdust bait been used. The difference between the long and short sawdust haul is seen to be no more than 3 or 4%.

TABLE 4.—RELATIVE COSTS OF BRAN-SAWDUST AND FLOUR-SAWDUST BAITS IF DELIVERED ENTIRELY AT ROSTHERN OR AT ROBSART

—	Total costs		Ratio	Estimated saving	
	"Bran" bait	"Flour" bait			
			%		%
1939					
Rosthern	$228,700	$138,700	61	$90,000	39
Robsart	235,500	152,400	65	83,100	35
1940					
Rosthern	74,700	38,500	51	36,200	49
Robsart	76,800	41,500	54	35,300	46

Besides the saving in the cost of materials the flour-sawdust bait reduces heavy carry-overs from one year to the next, as frequently occurs with bran. Flour is required in such relatively small quantities that it can readily be obtained and trucked in case of emergencies, while it takes comparatively little storage space. Another feature of this bait is that with its high proportion of sawdust it is less attractive to livestock than bait which is half bran.

DISCUSSION

The continued research in grasshopper baits by all workers has resulted in great progressive reduction of the cost of bait with little or no loss of efficiency. The savings thus represented—which, incidentlly, are many times greater than the costs of such research—have had a very important influence upon both the general and administrative acceptance of grasshopper control.

Parker (3) found that the inclusion of citrus fruit, as in the Kansas grasshopper bait formula, was not warranted. Further economies have since been obtained by the introduction of the 1:1 bran-sawdust bait in place of baits in which bran was the only carrier. The present paper has carried on this idea by showing that the still cheaper 1:13 flour-sawdust bait as used in Saskatchewan is equally effective. Some actual savings in this province from the changes of formulae have been presented.

The economic and administrative significance of these progressive developments may be readily seen from Table 5, which shows the *relative* costs of baits used at different periods. Since the costs per dry ton are based upon the average price of each material for the entire 1920-42 period, the influence of changes in bait formulae upon campaign costs is clearly shown. The average cost per ton in 1938-42 represents a 78% reduction from the figure for 1920-23 and 45% from that for 1932-37. The latter saving was entirely attributable to the substitution of flour-sawdust for bran-sawdust as the poison carrier.

TABLE 5.—INFLUENCE OF CHANGES IN BAIT FORMULAE UPON CAMPAIGN COSTS

Basis of comparison	Comparable costs per ton	1934 campaign	All campaigns 1919-42 incl.
1. At 1920-23 rate	$35.18	$817,600	$3,155,900
2. At 1932-37 rate	14.23	330,700	1,276,500
3. At 1938-42 rate	7.89	183,400	707,800
Difference between 1 and 3		634,200	2,448,100
Tonnage (dry weight)		23,240	89,700

Had it been necessary to use the expensive 1920-23 bait formula throughout all these years, it seems definite that in 1934 no province-wide campaign would have been undertaken, in view of the scale of the outbreak and the severe economic depression. In that case losses would have been tremendous. On the other hand, had the present flour-sawdust bait been developed by 1934 it would greatly have eased the administrative decision and financial burden. Even regardless of cost, had an all bran bait been in use in 1934, it seems certain that sufficient material would not have been available. The quantity of bait actually used in 1934 was nearly one-third greater than the total tonnage for the entire 1919-23 series of campaigns.

Although the general cheapening of baits has indeed been fundamental to the enormous growth of grasshopper control campaigns, not only in Saskatchewan but also in other parts of North America, there is no reason to suppose that the ultimate has yet been reached in this respect. For example, further experiments in co-operation with the Brandon Laboratory (Handford and Putnam (2)) indicate that only 1 volume of flour to 27 of sawdust may be as effective as the 1:13 flour-sawdust bait; although with the greater proportion of sawdust, its age may be an increasingly important factor. It should be kept in mind that the critical figure is that of cost per acre. Thus it may eventually be possible (e.g. Paul (4)) to achieve a lower net cost by the use of a bait which, even if costing more per ton, produces effective kills at much lower rates of application and under a wider range of conditions. Further economies and more effective grasshopper control can be obtained by a careful farm program which includes the judicious use of tillage together with timely and proper spreading of bait. The unit cost of bait, however, will always remain an important element.

SUMMARY

The data presented show that a grasshopper bait in which the carrier consists of 1 part by volume of low-grade flour to 13 parts of sawdust has given equally as good kills as the more expensive bait of equal volumes of bran and sawdust, under conditions representative of the northern Great Plains; liquid sodium arsenite was the poison used with both carriers, with no other ingredient except water in suitable proportions. It is shown that because of its efficiency, availability and low cost, the flour-sawdust bait has since 1938 been used almost exclusively in Saskatchewan, where it was first adopted on a campaign-wide scale. The minimum savings in this province, resulting from this step, have averaged approximately 45%. In the major campaign of 1939 this represented a sum of about $88,000.

The aggregate savings have had an important bearing upon the administrative aspects of grasshopper control. Some other advantages of the bait are brought out, as well as the main precautions which must be observed to ensure its full efficiency.

ACKNOWLEDGMENTS

The writers consider that great credit is due to S. H. Vigor, Field Crops Commissioner, Regina, for assuming the considerable administrative responsibility involved in being the first to use the flour-sawdust bait in a major campaign. Mr. Vigor also at our request calculated the relative costs shown in Table 4. Throughout our work the Saskatchewan Department of Agriculture has closely co-operated by supplying materials and facilities and by making observations of results.

We are indebted to Dr. R. H. Handford of the Dominion Entomological Laboratory, Brandon, Manitoba, in co-operation with whom the grasshopper bait experiments of 1940 to 1942 were conducted, for the analysis presented in Table 3.

Dr. J. R. Parker and colleagues of the United States Bureau of Entomology and Plant Quarantine have been generous in their interest and frank in discussions of mutual problems.

Assistance in the experimental work here reported was given by V. L. Berg, W. B. Fox, H. W. Moore, L. G. Putnam and D. S. Smith, to whom we desire to express our appreciation.

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LIFE HISTORY STUDIES OF THE PEA MOTH, *LASPEYRESIA NIGRICANA* (STEPH.), ON THE GASPE COAST[1]

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In the first paper of this series (2), of which this is the second, the history and distribution of the pea moth, *Laspeyresia nigricana* (Steph.), in Canada was outlined. In the present paper the records of several years observations on the life history of this insect in Bonaventure County, on the Gaspe Coast, Province of Quebec, are presented. (A summer laboratory was located at St. Godfroi in 1936-38 and at New Carlisle in 1939-42. These two places are about 12 miles apart on the coastal range facing the Bay of Chaleur, and the climatic conditions are very similar.) An attempt is also made to compare these data with all other recorded observations on the life cycle of this insect that have been published by other workers in Canada and the United States.

In Canada at least, accurate information on the life history of the pea moth has been greatly needed for some time. While studies of the life cycle of the insect in other countries may give an approximation of what to expect in this country, such information requires careful checking under more local climatic conditions. As the climatic reactions of any species may vary considerably between one continent and another and between different regions of the same country, it is necessary that these data should be obtained from the particular region in which control studies are being carried out. Accumulation of such information also tends to add to the general sum of knowledge of the reactions of the species to different environmental conditions. Accurate knowledge of the life cycle of the pea moth is found to be of particular significance when one is faced with the problem of formulating adequate control measures.

With most life history studies the use of the calendar in attempting to pin down the time factors between the various stages of development of an insect species is convenient, popular, and has some definite value. However, it is recognized that seasonal conditions may vary greatly from year to year and hence a calendar index is not always a reliable basis for the timing of control measures. Correlations of the stage of development of the host plant, the development of other plant growth, weather conditions, etc., with the critical stages of development of the insect species are frequently useful and important. These methods are used whenever feasible by the economic entomologist, but the relation of the significant stages of development of an insect to the calendar can not yet be completely disregarded in such studies. In the present paper a calendar index is used, but the different events in the life cycle of the insect have also been linked with other events wherever any significance was observed.

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In a general way the life history of the pea moth bears some resemblance to that of the codling moth. Like the latter insect, the pea moth hibernates as a caterpillar within its cocoon and the adult moths are on the wing the following year about the time their host plants are in bloom and the fruit beginning its development. With both insects, knowledge of the period of adult emergence and oviposition is of considerable importance if insecticidal methods of control are to be of any value. In addition, the present popular methods of pea moth control by clean-up and soil cultivation are both based on accurate knowledge of other phases of the life cycle, such as the period of emergence of the larvae from the pea pods, time of pupation, etc.

LIFE HISTORY

Adult Emergence

The first record on adult emergence in this country appears to have been made by Fletcher in 1897 (5) when he records finding a pea moth adult on July 12. The following year (6) he found the first pea moth on July 13. In both these years the last moth he observed appeared on July 15. From our present knowledge of this insect this total emergence period recorded by Fletcher appears much too short, and may possibly represent the period of peak emergence. Fluke (9), working in Wisconsin, records the first adults as appearing on July 14 and July 12 in 1920 and 1921. In the former year Fluke found the peak of emergence as occurring on July 18 and saw the last adult on July 30. In the latter year the last adult was observed on August 5. Studying this insect in Nova Scotia during the summer of 1918, Brittain (3) records pea moths emerging from July 12 to August 7 (but comments on the presence of a partly grown larva being found in a pea pod on July 18 and several others on July 21). In 1919 he found the first adult on July 12. Hanson and Webster (11) studied the life cycle of this insect in the State of Washington and in 1936 recorded an adult emergence period extending from June 1 to July 25 with maximum emergence occurring around the first two weeks of July. They also record the presence of a partial second generation of moths that "started to emerge late in July and continued through the fall."

The growing season of 1936 on the Gaspe coast was later than the average and as our pea moth studies in these regions were incepted at this time, adult emergence was determined by periodic search for the moths around the developing pea vines of the St. Godfroi district. The first adults were observed on Tom Thumb peas near Shigawake on July 18 and on Tall Telephone peas at St. Godfroi on July 19. However, by July 20 moths were quite numerous throughout the entire St. Godfroi district and it is quite likely that the first moths were flying some time before the first dates recorded. In this year the last adult was seen on August 15. In the autumn of 1936 experimental soil plots were seeded with pea moth larvae and the process repeated each year thereafter so that more definite records of adult emergence were obtained in the years 1937-41. During these years the first pea moth adults were recovered on the following dates: 1937, June 25; 1938, June 10; 1939, July 9; 1940, July 4; and 1941, June 30. The peaks of emergence were as follows: 1937, July 17-21; 1938, July

19-25; 1939, July 24; 1940, July 15; and 1941, July 30. The last moths appeared on the following dates: 1937, July 24; 1938, August 4; 1939, August 13; 1940, August 8; and 1941, August 21. The total emergence period extended for 30, 56, 36, 36, and 53 days, respectively. Fluke's (9) records show an emergence period of 48 days in Wisconsin, Hanson and Webster (11) one of 54 days in Washington, and Brittain (3) one of only 27 days in Nova Scotia.

The charts which appear at the end of this paper show the relationships of sunshine, temperature, and precipitation to the emergence of pea moth adults during the seasons of 1937-40 on the Gaspe coast. In this connection it will be observed that bright and warm spells usually preceded the maximum emergence of the moths. Precipitation is apparently also an important factor in pea moth emergence, particularly when it follows a bright warm period. It must be remembered that the cocoons, containing the hibernating pea moth larvae, lie as a rule only a short distance beneath the soil surface and thus should be easily influenced by even slight precipitation as well as changes in air temperature and light intensity. Instead of precipitation tending to retard emergence our records indicate an assisting action for this function. Thus it may be generally stated that the emergence of the pea moth adults tends to follow a bright and warm period of weather, and this emergence is assisted, or even accelerated, by an adequate supply of moisture.

The chart of adult emergence presented by Fluke (10) would indicate a steady and rather rapid rise in the number of emergents from the time the first adult appears until the peak of emergence is reached. However, the conditions recorded by Hanson and Webster (11), in this regard, are more nearly in conformity with our own findings. Adults may be appearing for as long as 2 or 3 weeks before the main peak of emergence has been reached. This factor needs consideration when chemical control is contemplated and also when the value of planting early varieties of peas is under consideration.

As a general rule Tall Telephone peas are usually coming into full bloom about the time of maximum emergence of pea moth adults. However, as pointed out above, quite a number of adults may be on the wing before this time of pea blooming. It thus is evident that all the moth adults do not have their time of emergence at all well correlated with the development of their cultivated host plant. On the other hand, the time of blooming of some of the wild host plants of the pea moth is usually earlier than that of cultivated peas. From this it might be assumed the early emerging pea moths are tending to conform to the stage of development of the wild hosts and not of the cultivated host plant. The ability of some of these early emerging adults to produce offspring which attack the stems and buds of the pea plant before blooming has occurred has already been recorded by Perron (14).

The period of adult emergence is spread over many weeks, lasting at least a month and sometimes as long as 6 to 8 weeks. However, a main peak of emergence is usually rather well marked, although, in some years, this peak may be spread over a number of days.

Preoviposition Period

Fletcher (7) apparently noticed the presence of a preoviposition period for the pea moth in 1900 when he makes the observation that he did not think that the moth always lays its eggs in the very early stages. Fluke (9) found that "about 3 days after the first moths emerged egg deposition began," and Brittain (3) records a preoviposition period of 4 to 7 days and states that mature eggs were found in the female 3 days after emergence. On the Gaspe coast it was found that the preoviposition period may be as short as 4 days and as long as 8 days. Weather conditions prevailing at the time of moth emergence or immediately thereafter appear to shorten or lengthen the preoviposition period. The normal time between adult emergence and the beginning of oviposition seems to be around 5 to 6 days.

Egg Laying

In 1898 Fletcher (6) recorded pea moth eggs laid after the middle of July, and in 1905 (8) that the eggs were laid on young pea pods as soon as they were formed. Fluke (9) in 1919 found the first eggs on July 17, the greatest number on July 19-20, and the last ones on July 31. Hanson and Webster (11) found eggs laid during June, July, and August. Brittain (3), in 1938, reported egg laying as occurring during the last 3 weeks of July and the first week of August.

Searching for the eggs of the pea moth in the field is an exacting task as they may be laid on any part of the pea plant above the ground, as well as on blades of grass, etc., in or around the pea fields. Their wild host plants are also usually abundant and in bloom during this time. Coupled with these conditions is the fact that the eggs are small and inconspicuous. Thus some natural reservations accompany our data on this point. On the Gaspe coast the first eggs were observed on the following dates: 1936, July 26; 1937, July 11; 1938, July 16; 1939, July 15; 1940, July 4; and 1941, July 8. Our records show the peak of egg laying to have occurred around the following dates: 1936, July 27; 1937, July 26; 1938, July 29; 1939, July 31; 1940, July 20; and 1941, August 4. Egg laying usually tapers off to end around the middle of August but has been observed ending as early as August 1 (1937) and as late as August 23 (1936 and 1941).

Egg Maturity Period

The time required between oviposition and hatching of the eggs is recorded as 7 to 10 days by Fluke (9), 7 to 8 days by Cameron (4), 8 days by Hanson and Webster (11), and only 2 to 3 days by Brittain (3). When the eggs are first laid they are whitish in colour, but by the end of the 2nd to 3rd day this has changed to a reddish tinge which deepens steadily until about the 6th to 7th day. Just a day or so before the eggs are ready to hatch small black spots are visible through the egg shell. Hatching was found to occur around 6 to 8 days after oviposition, although shorter and longer periods have been observed (5 to 9). Hatching of the eggs may be quite rapid and has been timed at 90 seconds for the complete operation. The young larva is usually quite active from the moment of emergence.

Larval Development

According to our records the first larvae noticed in the pea pods were: 1936, August 2 (late season); 1937, July 29; 1938, July 23; 1939, July 28; 1940, July 9; 1941, July 17. The peak of infestation in peas usually occurred during the first two weeks of August, with injury becoming more and more pronounced thereafter.

Fluke (9) recorded the larval period as 16 to 26 days in 1920 and 10 to 27 days in 1921 (10). Miles (12) found the duration of the larval stage in England as 22 days, while in Latvia, Ozolo (13) determined the larval period as 17.5 days at 20° C. (68° F.) and 65 days at 11° C. (51.8° F.). Hanson and Webster (11) observed a feeding period in the pea pod of 19 to 28 days with a maximum period in vetch of 35 days, while Brittain (3) states that 17 to 20 days are spent in the pea pod. Cameron (4) found that the larvae moult 4 times during their development, passing through 5 stadia.

The time necessary for the larvae to complete their development and the total time they may spend in the pod are not always the same. Provided a larva finds plenty of nourishment it may develop rather quickly, but some larvae may remain in the pods for rather lenghty periods. Normally, the larvae appear to require about 3 weeks to 1 month to complete their growth.

Larval Emergence from Pea Pods

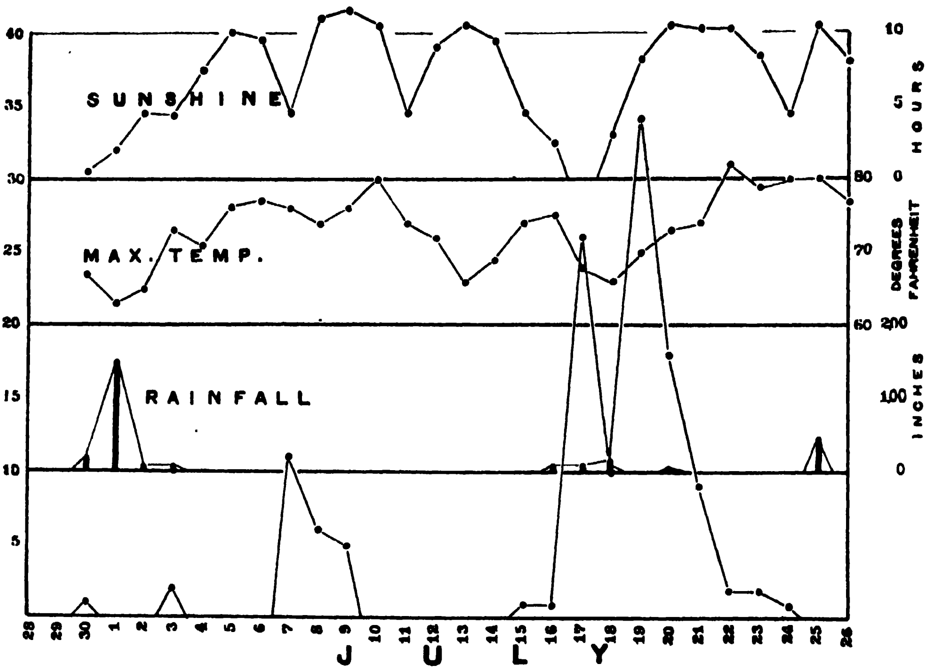
The periods during which the larvae are emerging from the pea pods were found to cover a much longer time than had been previously recorded. In fact it was usually necessary to close down our work for the season before the last of the larvae decided to come out of the pea pods. Thus a few larvae were still emerging by October 1 in 1936, and on October 10 in 1939 and 1941. On these occasions tins of soil were placed under pea hoppers used for emergence studies at the time of our departure and were found to contain a few pea moth cocoons the following spring. However, it was found that the greatest number of larvae usually emerge from the pea pods during the last week of August and the first week of September.

As soon as a larva leaves a pod and drops to the ground it is the common practice for it to try to get out of sight beneath the soil surface as rapidly as possible.

Cocoons

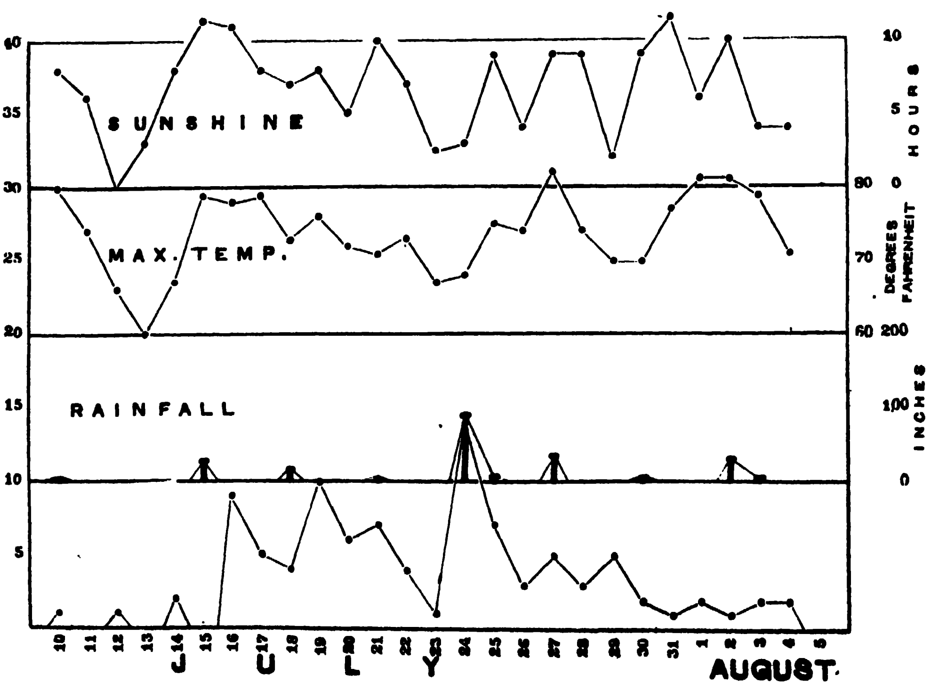
On entering the ground the larvae spin small silken cocoons into which they work soil particles. It has been found that if soil is not available other extraneous material may be made use of or the cocoon may be formed occasionally without the assistance of any foreign material. Normally, however, the cocoon looks like a small lump of earth and it is not easy to distinguish it from the surrounding soil. The pea moth hibernates within this cocoon as a larva and pupation does not occur until the following spring. Thus 9 to 10 months of the year are spent within the cocoons as hibernating larvae.

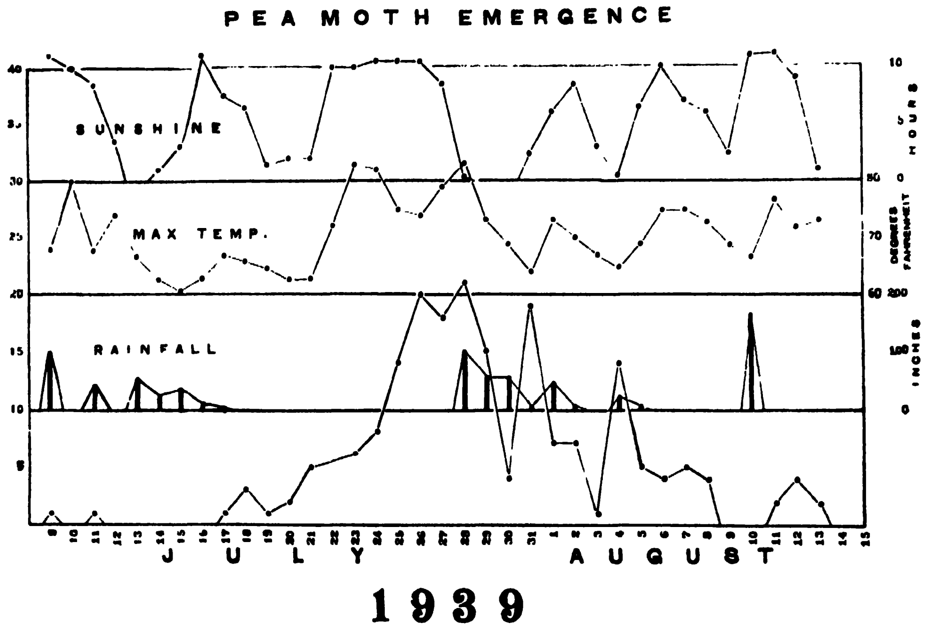
PEA MOTH EMERGENCE



1937

PEA MOTH EMERGENCE





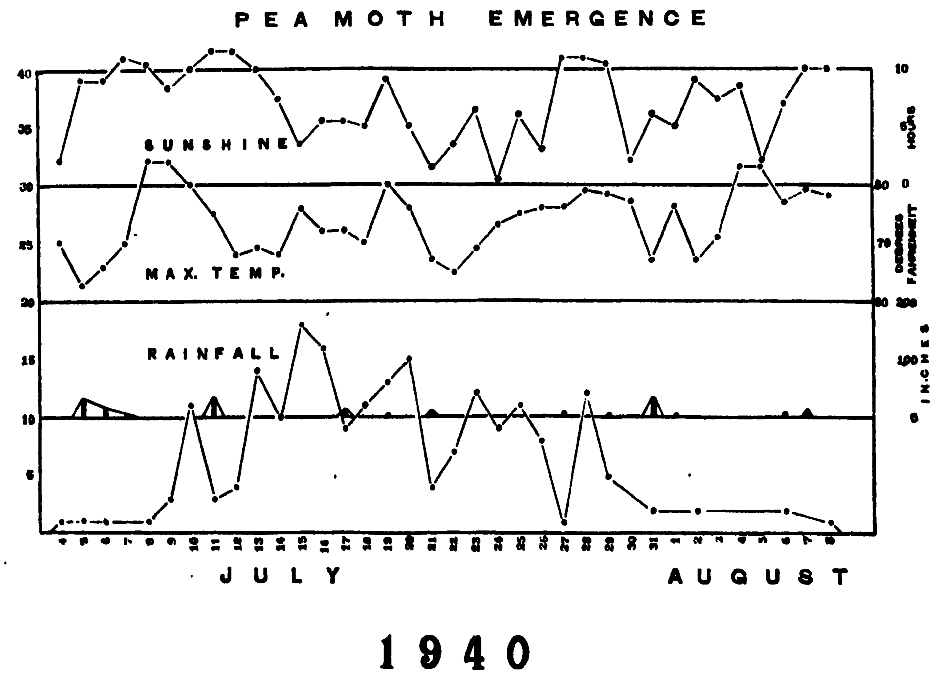


FIGURE 1. Emergence of pea moth in successive years 1937 to 1940. The lower line in each graph shows emergence in percentage.

Pupation

Fluke (9) found pupation taking place on June 15, with the moths emerging 3 to 4 weeks thereafter. Brittain (3) records the first pupa on June 19, 1919, in Nova Scotia with the first adult appearing on July 12. He concluded that the duration of the pupal stage "would seem to be in the neighbourhood of from 3 to 4 weeks." Cameron (4) found that pupation takes place in June and the end of May, and that its duration lasts about 2 weeks.

As might be expected from our knowledge of the length of the period of emergence of pea moth adults, pupae are also sometimes to be found over a rather lengthy period. Thus on the Gaspe coast in 1941 the first pupa was found on June 9 with a peak of pupation apparently being reached on July 10 and the last pupa being found on July 29. The first pupa was not found until June 23 in 1939 and in 1938 the peak of pupation was around June 30. It would appear that the pupation period may be as short as 10 to 14 days and sometimes last as long as 3 weeks.

Second Generation

Working on this continent, Hanson and Webster (11) record the presence of a partial second generation of pea moths. This condition has also been observed by some other workers in Europe. As yet, we have no direct evidence that a second generation occurs on the Gaspe coast. It has been found that if pea moth larvae are allowed to spin up their cocoons in soil in the autumn and then maintained thereafter at room temperature (and sufficient moisture) that most of these larvae will pupate and emerge as moths some time around December of the same year.

SUMMARY

Records of observations on the life history of the pea moth, *Laspeyresia nigricana* (Steph.), in Bonaventure County, Province of Quebec, covering the period of 1936-1942 are presented, and these data are compared with all other available records of the life cycle of the insect made by other workers in North America. The times of adult emergence, preoviposition period, egg laying, egg maturity period, larval development, larval emergence from pea pods, cocoon formation, pupation, etc., are dealt with. Fourteen references to the literature are given.

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BOOK REVIEW.

MODERN POULTRY FARMING by L. M. Hurd. The MacMillan Company, Canada, 1944. (Rural Science Series.) $4.50.

Described in the preface as "a practical guide for both large and small poultry keepers and those interested in starting a poultry enterprise" this text fulfils this purpose to a rather gratifying degree. The difficulty of interpreting the scientific in practical terms which are understandable to a great many people of varying degrees of educational training and outlook is generally well appreciated and the author has produced a very readable book which will be found of value to poultryman, student and poultry specialist.

Illustrative figures are clear and well chosen. In some instances, however, the tabular material chosen seems to be unnecessarily complicated in arrangement, particularly in the chapter dealing with "investment, returns and expenses in poultry farming". The fundamental requirements in starting a poultry enterprise are clearly set forth and lay a firm foundation for the application of the detailed instruction to follow. The choosing of the most suitable breed, housing, incubation, brooding, feeding, management, breeding for egg production, and poultry diseases are all well but briefly handled. Under the above headings several matters are worthy of comment: first, that although excellent detailed plans for brooder houses are shown, laying houses have not been accorded the same treatment to an equally satisfying degree; second, illustrations on the subject of preparing dressed poultry for market are particularly well chosen; third, the very controversial subjects of inheritance of and culling for egg production are perhaps not placed in the proper perspective with regard to the uncertainty of existing recommended practices; and last, the subject of disease is given a very important place in the book, which those who are in a position to know will realize is merited. All in all, the book deals with principles in a thorough and lucid manner giving detail to a sufficient degree, and is well worth careful study by those for whose attention it has been specifically published.

H. S. GUTTERIDGE.

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STUDIES IN SEED POTATO TREATMENTS

III. AGENCIES AND PRACTICES THAT REDUCE THE STRENGTH OF MERCURIC CHLORIDE SOLUTIONS, CAUSING INEFFECTIVE DISINFECTION[1]

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The recent publications of studies I and II dealt with methods for testing and adjusting corrosive sublimate solutions (2, 3). The succeeding paper (4) concerns the repeated use of corrosive sublimate solutions by means of strength-control and by acidulation with acetic acid. Some of the experiments of this paper were completed before the above published methods were developed. The original investigation has been expanded to include a systematic study of the indiscriminate and common practices of farmers in treating procedures, with the ultimate purpose of recommending, if possible, a definite procedure by eliminating the offending agencies.

The authors have confirmed the results of Weimer's systematic investigation (10). Weimer and others (6, 9, 10, 11) concluded that a general procedure of treatment was impossible and unreliable, because of the type and quantity of soil, refuse, sacks, etc. which may accompany the potatoes into the solution, but that some definite method was needed to meet the individual farmer's requirement.

The most commonly used seed potato disinfection in Canada is the standard long soak for $1\frac{1}{2}$ hours in 1: 1000 mercuric chloride solution. Accordingly, this treatment was employed to ascertain the losses of mercuric chloride effected by washed potatoes, different types of treating vessels, sacks and soils. The possible effects of well waters (6) and of the reducing substances in the potato tuber (5, 8) are also considered. In preparing the disinfection solutions, the common error of attempting to dissolve the mercuric chloride crystals in cold water, was eliminated by the use of a 5% "stock" solution, prepared with hot water (3).

Methods of Analysis

In Table 1, mercuric chloride was determined as the sulphide (1), but in subsequent experiments, by the authors' laboratory method (2), and/or by Jamieson's volumetric method (7) as noted in the tables, Jamieson's being considered as the standard and more reliable for general mercury

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analyses. For the experiments with sacks and soils, the authors' method was not always applicable, due to the highly reducing substances present in some sack and soil solutions, but when these reducing substances were excluded, the method was found simple, quick and sufficiently accurate.

LOSSES OF MERCURIC CHLORIDE

Reduction Effected by Treatment Vessel

Solutions of determined strengths were allowed to stand in galvanized iron, wooden and glass vessels for various periods of time, Tables 1, 2 and 3. The mercuric chloride was determined as gram per 1000 ml. solution before and after the period of treatment.

TABLE 1.—REDUCTION BY GALVANIZED IRON VESSELS

Reduction period	Vessel No. 1		Vessel No. 2	
	$HgCl_2$ per litre	Reduction	$HgCl_2$ per litre	Reduction
	gm.	%	gm.	%
At start	.491		.487	
1 hour	.344	29.9	.347	28.8
5 hours	.230	53.2	.235	51.8
24 hours	.041	91.7	:048	90.2

It is not likely that metal vessels are being used these days, but the rapid loss of mercuric chloride, shown in Table 1, serves to give some idea of the effect of nails and wire of crates and hampers, which are used as containers of potatoes in treating practices.

TABLE 2.—REDUCTION EFFECTED BY WOODEN PAIL

Reduction period	$HgCl_2$/1000 ml. solution*		Reduction		Remarks
	Start	Finish	Total	1½ hr. rate	
	gm.	gm.	%	%	
1½ hours	.955	.919	3.8	3.8	Scrubbed—no previous treatment
17½ hours	.891	.750	15.8	1.4	After 2 batch treatments
16 hours	.966	.884	8.5	.8	After 4 batch treatments
90 hours	.996	.708	28.9	.5	After 7 batch treatments
1½ hours	1.006	1.006	None		After 7 batch treatments
24 days	.974	.893	8.3	.02	After 9 batch treatments

* Determined by the authors' laboratory method.

The wooden pail was about 10-litre capacity, in which 5 litres of solution, prepared from tap water and 5% "stock", were used. The loss of mercuric chloride for the first 1½ hours was 3.8% (Table 2). It may be considered economical to allow solutions to stand overnight in wooden vessels for adjustment and use the next day; the over-night loss was 15.8%

after 2-batch treatments but only 8.5% after 4 treatments. After 9 treatments had been made when the vessel had become well seasoned with mercuric chloride, the total loss of mercuric chloride in the solution, standing for 24 days was 8.3%. The loss rate per 1½ hour diminished from 3.8% at the start to 0.02% after 24 days.

TABLE 3.—REDUCTION EFFECTED BY GLASS VESSEL

Reduction period	$HgCl_2$/1000 ml. solution*		Reduction	Remarks
	Start	Finish		
	gm.	gm.	%	
14 hours	.895	.898	None	After 4 batch treatments
16 hours	.847	.855	None	After 5 batch treatments
8 days	.923	.934	None	After 8 batch treatments

* Determined by the authors' laboratory method (2).

No loss of mercuric chloride occurred in the glass vessel (Table 3). Tap water, likewise, had no reducing effect and, consequently, it would appear that any good drinking water can be safely used to prepare treating solutions.

Reduction Effected by Washed Potatoes

The potatoes were washed by soaking in water 5 to 10 hours. Eight- to nine-pound lots of the seed, a mixture of varieties and sizes, 1½ to 12 ounces, were immersed in 5 litres of mercuric chloride solution for 1½ hours. The strength of the solutions was determined by the laboratory method of the authors (2) before and after the treatment. The results are shown in Table 4.

TABLE 4.—REDUCTION EFFECTED BY WASHED POTATOES IN GLASS VESSEL

Successive treatments	$HgCl_2$/1000 ml. Solution		Reduction
	Start	Finish	
	gm.	gm.	%
1st lot	.990	.930	6.1
2nd lot	.942	.869	7.7
3rd lot	.961	.924	3.9
4th lot	.946	.895	5.4
5th lot	.963	911	5.4
6th lot	1.005	.950	4.5
7th lot	1.018	.985	3.2
8th lot	1.081	.962	11.1
9th lot	1.009	.974	3.5
9 treatments averaged			5.6

The solution was made up fresh for the first lot and mercuric chloride 5% "stock" and water were added before each subsequent lot treatment. The loss of mercuric chloride varied from 3.2 to 11.1% per treatment,

averaging 5.6% for 9 batches. Cut tubers and the size of tubers probably account for most of the variation; the presence of some soil or broken sprouts, in spite of the tubers being washed, may also have had some effect.

Reduction Effected by Sacks

Empty soiled sacks, of 100-lb. capacity, which had been used for various purposes before containing potatoes, were lightly shaken before treatment. Each sack was immersed and thoroughly wetted in 5 litres of carefully prepared 1 : 1000 mercuric chloride solution in a glass vessel and allowed to remain for 1½ hours. Excess solution was lightly pressed out as the sack was removed and the mercuric chloride determined in the resultant solution.

TABLE 5.—REDUCTION EFFECTED BY DIRTY USED SACKS

	Gunny sacks		Grain sack	Sugar sack
	No. 1	No. 2		
Start ($HgCl_2$ per litre)	1.000	1.000	1.000	1.000
Finish*	.553	.609	.650	.849
% reduction	44.7	39.1	35.0	15.1
Finish† ($HgCl_2$ per litre)	‡	‡	‡	.851
% reduction				14.9

* Determined by Jamieson's volumetric method.
† Determined by authors' laboratory method.
‡ Not determinable by authors' laboratory method.

The strength of mercuric chloride solutions may be reduced by 15% from sugar sacks to as much as 45% from gunny sacks in 1½ hours (Table 5). The sugar sack-solution was the only one determinable by the authors' method (2). Two of the sack-solutions were titrated with standard permanganate solution: aliquots of 100 ml. solutions from gunny sack No. 2 and grain sack reduced 7.45 ml. and 1.70 ml. 0.1 N potassium permanganate, respectively, corresponding to 39.1% and 35% reduction of mercuric chloride. Tap water, which was used for all treatment solutions in this paper, had no reducing effect on 0.1 N permanganate solution.

The reducing effect of gunny sack No. 1 and the sugar sack, after being washed well, dried and retreated in fresh solution for 1½ hours is shown in Table 6.

TABLE 6.—REDUCTION EFFECTED BY WASHED SACKS

	Gunny sack No. 1		Sugar sack	
Start ($HgCl_2$ per litre)	1.000		1.000	
Finish ($HgCl_2$ per litre)	.723*	.729†	.940*	.926†
Percentage reduction	27.7	27.1	6.0	7.4

* Determined by Jamieson's volumetric method.
† Determined by the authors' laboratory method.

From Tables 5 and 6, gunny sack No. 1 effected 44.7% loss of mercuric chloride before being washed compared to 27.7% after being washed, and the sugar sack effected 15.1% loss before compared to 6.0% loss after. The effect of sacks in reducing the strength of mercuric chloride solutions is probably both chemical and physical in nature, the latter effect possibly adsorption of mercuric ions on the fibre surfaces of the sacks; the applicability of the authors' method for determining mercuric chloride (Tables 5 and 6) supports this conclusion.

Another factor, not appearing in Tables 5 and 6, is the removal of solution by sacks after each treatment. When potatoes are immersed in sack containers, water and stock mercuric chloride must be added to restore the volume and strength of the solution for the next batch.

TABLE 7.—SOLUTION REMOVED BY SACKS

	Gunny sack No.1	Grain sack	Sugar sack
Allowed to drip	710 ml.		300 ml.
Percentage of original volume	14.2		6.0
After being "wrung out"	595 ml.	400 ml.	200 ml.
Percentage of original volume	11.9	8.0	4.0

Table 7 shows the amounts of solution removed by sacks from 5 litres of 1 : 1000 solution of mercuric chloride. This removal of solution by sacks, therefore involves losses of mercuric chloride which are additional to the losses shown in tables 5 and 6.

The Reduction Effected by Soils

The soil samples were representative of three types from which potatoes had been harvested. The sample of sweepings was obtained from a warehouse floor. The sandy soil contained less organic and vegetable matter than the other samples. One pound of each sample was stirred into 5 litres of carefully prepared 1 : 1000 solutions of mercuric chloride in a glass vessel and allowed to stand for 1½ hours.

TABLE 8.—REDUCTION EFFECTED BY SOILS

	Sandy		Sweepings		Clay loam		Sandy loam	
Start ($HgCl_2$ per litre)	1.000		1.000		1.000		1.000	
Finish ($HgCl_2$ per litre)	.889*	.877†	.769*	‡	.735*	‡	.707*	.693†
Percentage reduction	11.1	12.3	23.1		26.5		29.3	30.7

* Determined by Jamieson's volumetric method.
† Determined by authors' laboratory method.
‡ Not determinable by authors' laboratory method.

According to Table 8, the strength of mercuric chloride solutions was reduced considerably by soils, varying from 11.1% for sand to 29.3% for sandy loam. The presence of the highly adsorbent substances, viz., the

straw and vegetable matter in the sweepings and the colloidal particles in the clay loam, is significant. Consequently, in the solutions containing the sweepings and the clay loam, where the authors' method was not applicable, it is possible that physical adsorption predominated to reduce the strength of mercuric chloride; in the solutions containing the sandy loam and the sandy soils, the loss of mercuric chloride may have resulted more from chemical reduction than from physical adsorption.

CONCLUSIONS

For the standard long soak treatment, it appears conclusive that sacks, crates or hampers, soils and unsuitable treatment vessels with metal contacts with the solution rapidly render mercuric chloride solutions useless for seed potato disinfection. The rapid loss of mercuric chloride in disinfection processes may be due both to chemical reduction and physical adsorption. Well waters of good drinking quality (Table 3) and the reducing substances of the potato tuber (5, 8), if cut tubers be discarded for seed, may be considered as negligible reducing factors, compared to sacks, soils, etc.

In order to ensure effective disinfection by the long soak treatment of successive lots of potatoes by the repeated use of the original solution, it is necessary to exclude the reducing agencies from the process, and to maintain a strength-control of the mercuric chloride solution. The following procedure is recommended:

(1) Use concrete, porcelain, or wooden treating vessels, free from metal contacts with the solution.

(2) Do not treat potatoes in sacks, or in crates and hampers held together by nails and wire.

(3) Remove as much soil and vegetable matter as possible from the tubers, preferably by soaking in water, before treating.

(4) Test and adjust the strength of mercuric chloride solutions before treating successive lots of tubers according to the easy and effective control methods of the authors (2, 3).

SUMMARY

The loss of mercuric chloride during seed potato disinfection is possibly due to both chemical reduction and physical adsorption: the actual losses effected, in 1½ hours from 5 litres of 1 : 1000 solution, by various agencies were 15 to 45% by dirty used sacks; 6 to 28% by washed sacks; 11 to 30% by 1 pound of soils; 3 to 11% (average 5.6%) by washed potatoes; 0.5 to 3.8% by wooden vessels. Potato tubers have a negligible reducing effect, if the cut tubers be discarded for seed treatment. Any well water of drinking quality can be used to prepare the solutions.

The repeated use of the original solution for effective disinfection by the standard long soak process is possible by excluding the reducing agencies and by maintaining strength-control as follows: (1) Remove as much soil and refuse as possible from the tubers, preferably by soaking in

water for 3 hours or more; (2) Use concrete, porcelain, or wooden treatment vessels, free from metal contacts with the solution; (3) Discontinue the use of sacks and other potato containers, such as crates and hampers, held together by nails and wire, for immersing the tubers in the mercury solutions; (4) Test and adjust the strength of the mercuric chloride solution before each successive treatment by the authors' methods.

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STUDIES IN SEED POTATO TREATMENTS

IV. THE REPEATED USE OF CORROSIVE SUBLIMATE SOLUTIONS BY STRENGTH-CONTROL AND BY ACIDULATION WITH ACETIC ACID FOR EFFECTIVE DISINFECTION PRACTICE[1]

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In the preceding study of this series (6), the authors showed the nature and the extent of the losses of mercuric chloride, which may occur in the practice of the long soak disinfection. Earlier studies, I and II (4, 5), dealt with methods for testing and adjusting corrosive sublimate solutions. The present and concluding study concerns the numerous advantages of disinfection with acidulated corrosive sublimate solutions compared to the "standard long soak" with strength-control.

The long soak disinfection has been generally accepted as the standard and most effective control of potato tuber-borne diseases. The process, consisting of a 90-minute soak in 1 : 1000 mercuric chloride solution, viz., 4 ounces per 25 imperial gallons, has always been handicapped by the rapid loss of mercuric chloride. In practice, it has been customary to add ½ to 1 ounce of corrosive sublimate per 25 gallons solution, after each treatment in order to replenish the solution for the next batch and to discard the solution after 3 to 6 lot treatments (1, 2, 9, 11). This indefinite procedure was found unreliable[4] and entirely too expensive at the present costs of labour and materials (9).

Doubtless, more growers would disinfect their seed potatoes if less time were required. Nevertheless, the hot corrosive sublimate treatment (1, 2, 11), requiring only 2 minutes at 126° F. although effective, has never been popular. However, the acidulated mercuric chloride treatment (2, 3, 8, 9, 11) possesses merits which would seem to warrant its popular adoption. Acidulation prevented the usual rapid loss of mercuric chloride and afforded a high control of tuber-born diseases in as short a time as 5 minutes. Plummer and Bonde (9) preferred acidulation with acetic acid, which, they showed, was as effective as hydrochloric and was less injurious to tubers, human skin and clothing; 89% of rhizoctonia was controlled in 5 minutes; the original treating solution was used for 25 succesive lots of unwashed tubers without the need of any adjustment; the tubers were treated by hand in a porcelain vessel; the efficiency of the solution was not decreased when the time of treatment was increased to 10 minutes or longer.

To the farmer, the ultimate potato yield is the criterion of successful seed disinfection. Occasionally, when the seed has been planted immediately after being treated, especially in a dry season, decreased yields

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have resulted from disinfected-diseased-seed (2, 10, 12). The dormancy of seed, induced by disinfection, postpones the resprouting of the tubers and, when planted immediately, may delay the early growth by 2 to 3 weeks and accordingly adversely affect the yield. Consequently, in order to ensure substantially increased yields, seed should be treated preferably in the fall or winter or 30 days before planting in the spring. The exposure of the spring treated seed to light and air, for 2 to 3 weeks before required for cutting and planting, facilities the growth of thick, stubby sprouts (11) and contributes toward increased yields. It is important to label conspicuously any stored treated-seed, on account of the poisonous nature, to prevent the tubers being used as food.

Methods of Analysis

In the following experiments, mercuric chloride was determined by the laboratory method of the authors (4). Agencies and practices, which might have prevented the successful application of the method, were excluded from the long soak disinfection process; 50 or 100 ml. aliquots of the 1 : 1000 solution, without filtering, were found suitable. For the solutions, acidulated with acetic acid, it was found necessary to carry the titration to a distinct, permanent blue end point, in contrast to the bluish tinge end point for solutions containing no acid. The acidulated 2 : 1000 solution of mercuric chloride did not require filtering and 25 or 50 ml. aliquots were found satisfactory for titrations.

The authors' laboratory and field methods (4, 5) were compared with Jamieson's volumetric (7), in determining mercuric chloride in solutions, which had been used for the long soak potato disinfection. The results, in Table 1, represent averages, from triplicate analyses. The authors' simple titration methods, with their sharp end points, are rapid, convenient and sufficiently accurate, compared to the longer method of Jamieson, which requires a long precipitation and a subsequent slow titration with chloroform.

TABLE 1.—COMPARISON OF ANALYTICAL METHODS

Mercuric chloride per litre solution			Number of lots treated by solution
Authors' laboratory	Method of analysis Authors' field	Jamieson's volumetric	
gm.	gm.	gm.	
0.851		0.849	One
.729		.723	One
.926		.940	One
.942	0.925		One
.812	.800		Two
.962	.950		Two
.808	.786		Three
.946	.900		Three
.843	.833		Four
.962	1.000		Four

STRENGTH-CONTROL FOR EFFECTIVE DISINFECTION BY THE STANDARD LONG SOAK

These experiments were undertaken to determine how many successive lots of potatoes might be treated by the repeated use of the original solution. The strength of the solution was controlled by systematic testing and adjusting (4, 5). The tubers were washed by soaking in tap water for 3 hours or more. Eight-pound successive lots of washed seed were immersed for 1½ hours in 5 litres of aqueous mercuric chloride solution, prepared with 100 ml. of 5% "stock". Following the initial testing, the strength of the solution was tested 3 times after each treatment, viz., immediately after seed disinfection, again after the addition of water to restore the volume and finally, after the addition of the 5% "stock" to adjust the strength for the next batch.

In general practice, field or laboratory, after checking the initially prepared solution for strength of mercuric chloride, 1 : 1000, only one testing and adjustment per treatment is required, or possibly only one testing and adjustment for every 3 treatments, viz., after the addition of water to restore the volume. The general procedure and the changes of mercuric chloride content may be followed in Tables 2 and 3 for nine successive lot treatments of potatoes in glass and wooden vessels.

Treatment in Glass Vessel

Small tubers, weighing 1½ to 6 ounces, were treated in a glass vessel. The mercuric chloride losses, shown in Table 2, averaged 5.8% for 9 successive lot treatments. As the glass vessel exerts no reducing effect (6), the entire loss must have been effected by the small tubers with their large surface exposure.

TABLE 2.—EFFECTIVE DISINFECTION OF WASHED POTATOES IN GLASS VESSEL

Successive lot of washed tubers	Strength at start	*Strength after 1½ hours	Reduction of $HgCl_2$	Water added to restore volume	Strength after adding water	Ml. 5% "stock" added	Strength after adjustment
			%				
1	.990	.930	6.7	480	.841	16	.942
2	.942	.869	7.7	280	.812	19	.962
3	.962	.924	4.0	500	.808	19	.946
4	.946	.895	5.4	325	.843	16	.962
5	.962	.911	5.3	500	.815	19	1.005
6	1.005	.950	5.5	150	.923	11.5	1.018
7	1.018	.985	3.2	250	.930	7	1.081
8	1.081	.962	11.0	200	.923†		
9	1.009	.974	3.5				
Average			5.8				

* Strength denotes gram mercuric chloride per litre.

† After this stage, the solution stood for 8 days and required 175 ml. water and 10.5 ml. "stock" to adjust the strength for the 9th lot treatment.

Treatment in Wooden Vessel

Large tubers, weighing 8 to 12 ounces, were treated in a wooden pail, previously scrubbed, rinsed thoroughly and water-soaked for 24 hours. The loss of mercuric chloride averaged 5.7%, for the nine treatments, Table 3, part of this loss being effected by the wooden vessel (6), which

would average around 0.5 to 1%. Accordingly, the actual mercuric chloride loss, effected by the large tubers, themselves in wooden treating vessel, would average possibly around 4.5 to 5%.

TABLE 3.—EFFECTIVE DISINFECTION OF WASHED POTATOES IN WOODEN VESSEL

Successive lot of washed tubers	Strength* at start	Strength after 1½ hours	Reduction of $HgCl_2$	Water added to restore volume	Strength after adding water	Ml. 5% "stock" added	Strength after adjustment
			%				
0	.955	.919	3.8	150	.885	11.5	.978
1	.978	.898	8.2	215	.865	15.5	1.000
2	1.000	.935	6.5	525[1]	.712	29.0	.925
3	.925	.875	5.4	150	.848	15.6	.994
4	.994	.966	2.9	350[2]	.785	22.8	.994
5	.994	.922	7.2	225	.879	12.0	.994
6	.994	.946	4.8	200	.910	11.3	1.002
7	1.002	.966	3.6	225	.931	7.4	.986
8	.998[3]	.926	7.1	700[4]	.798	21.4	.994
9	.994	.974	2.0				
Average			5.7				

* Strength denotes gram mercuric chloride per litre.
[1] Solution had stood 18 hours before the addition of water.
[2] Solution had stood 16 hours before the addition of water.
[3] Before making 8th treatment, the solution had stood for 7 days and required 550 ml. water and 60.4 ml. of 5% "stock" for adjustment.
[4] Solution had been withdrawn for sampling purposes.

Although the comparatively large additions of water, to restore the volume, shown in data of Tables 2 and 3, caused greater reductions in strength than the individual treating processes on the 5 litre solution basis, this effect would be negligible on the 25 or 50 gallon-field-basis.

THE ACIDULATED CORROSIVE SUBLIMATE TREATMENT IN WOODEN VESSEL

As a preliminary experiment, 2½ litres of solution, containing 40 ml. of 5% "stock" mercuric chloride solution and 16.7 ml. of glacial acetic acid (99.5%) per litre, in a wooden pail, were stirred occasionally to ascertain the changes in acid and salt contents that occur. The effect of the wooden treating vessel on the mercuric chloride and acetic acid contents of the treating solution is shown in Table 4.

TABLE 4.—THE EFFECT OF WOODEN VESSEL ON THE MERCURIC CHLORIDE AND ACETIC ACID CONTENTS OF THE TREATING SOLUTION

Time in hours	Mercuric chloride			Acetic acid		
	Per 1000 ml. solution	Loss	Rate loss per 10′	Per 1000 ml. solution	Loss	Rate loss per 10′
	gm.	%	%	gm.	%	%
0	2.016			16.663		
½	1.968	2.33	.78	16.663		
17	1.680	16.7	.16	15.677	5.93	.06
21	1.624	19.4	.16	15.283	8.28	.07
22	1.600	20.6	.16	15.431	7.34	.06
39	1.488	26.2	.11	15.530	6.80	.03

The loss of mercuric chloride caused by the wooden vessel per 10-minute-treatment was less than 1% for the first few treatments, but for subsequent treatments, the loss rate diminished: after 17 hours the total percentage loss was considerable, being 16.7%, but the corresponding percentage rate loss per 10 minutes of 0.16% was quite small. Unfortunately, analyses were not made for the 5- and 10-hour periods. The loss of acetic acid was small and proportionately less than that of mercuric chloride.

The Effect of Successive Treatments of Unwashed Potatoes on the Acidulated Solution

A bag of Green Mountain potatoes was supplied by the Field Husbandry Division to study the losses of mercuric chloride that occur from successive lot treatments. Each lot of unwashed potatoes, 4 lb. per lot, was soaked for 10 minutes in 5 litres solution-mixture of acetic acid and mercuric chloride, contained in a wooden pail. The concentrations of the reagents used to prepare the treating solution and the results of the experiment are given in Table 5. The ultimate purpose of the experiment was to decide, from the losses of mercuric chloride and acetic acid that occur, how many successive lots of seed might be treated by repeated use of the original solution without the need of strength adjustment.

Twenty successive lots of seed were treated by hand, for 10 minutes each, in less than 5 hours; less than 10% mercuric chloride and 5% acetic acid losses were found in the final solution, Table 5; Plummer and Bonde, treating in a porcelain vessel for 5-minute periods, found a total loss of less than 8% mercuric chloride and 2% acetic acid, from 25 successive lots of potatoes and that 89% effective disinfection for rhizoctonia resulted as shown by examination of stem lesions. In the present experiment, with the doubled time of treatment, 10 minutes instead of 5, it is reasonable to say that the disinfection would be more than 90% effective and that considerably more than 20 successive lots of unwashed potatoes might be treated in wooden vessels.

It is significant that: acidulation (Table 5) prevented the rapid loss of mercuric chloride experienced in the non-acidulated solutions (Tables 2 and 3); the losses, according to Table 5, averaged less than 0.5% per treatment compared to about 6% in Tables 2 and 3; the mercuric chloride was depleted faster than the acetic acid in the acidulated solution.

The volume of the solution was measured at the end of the experiment to determine the amount removed by the treated tubers; less than 2% of the volume of solution was lost in removal by the tubers. On a 25- or 50-gallon solution-basis, the loss would be negligible, if neither sacks nor crates were used to immerse the tubers.

DISCUSSION

For the long soak process, Tables 2 and 3, the solution was used 9 times to treat successive lots of washed tubers by means of testing and adjusting for volume and strength before each subsequent treatment. Under such a procedure, the solution might be used indefinitely. It is

TABLE 5.—REDUCTION IN STRENGTH OF MERCURIC CHLORIDE AND ACETIC ACID EFFECTED BY SUCCESSIVE TEN MINUTE TREATMENTS OF 4 LB. LOTS OF UNWASHED POTATOES IN 5 LITRES OF ACIDULATED MERCURIC CHLORIDE SOLUTIONS

Successive lot treated	Mercuric chloride		Acetic acid	
	Gm. per 1000 ml. solution	Percentage lost	Gm. per 1000 ml. solution*	Percentage lost
0	2.032†		17.107‡	
1	2.008	1.13	17.206	
2	1.992	1.97	17.009	0.57
3	1.968	3.15	16.911	1.72
4	1.976	2.76	16.762	2.02
5	1.960	3.54	16.762	2.02
6	1 936	4 72	16 960	.86
7	1.920	5.51	16.960	.86
8	1.920	5.51	16.960	.86
9	1.896	6.69	16.566	3.16
10	1.904	6.30	16.862	1.43
11	1.888	7.09	16.762	2.02
12	1.872	7.87	16.911	1.15
13	1.880	7.48	16.762	2.02
14	1.880	7 48	16.664	2.59
15	1.872	7.87	16.615	2.88
16	1.864	8.27	16.566	3.16
17	1.872	7.87	16.664	2.59
18	1.856	8 66	16.762	2.02
19	1.856	8.66	16.469	3.73
20	1.832	9 84	16.368	4.32
Average per treatment		.492		.216

* Obtained by titrating 5 ml. of solution with 0.1 N sodium hydroxide and phenolphthalein indicator.

† Equal to 40 ml. of 5% "stock" per litre or 1 imperial gallon of 5% "stock", viz., 8 ounces mercuric chloride per 25 imperial gallons of treating solution.

‡ Equal to 16.7 ml. or 3¼ imperial pints of glacial acetic acid (99.5%) per litre or 25 imperial gallons of treating solution, respectively.

possible that testing and adjusting of the solution, after every 3rd successive lot, instead of after each treatment, may be sufficient, if tubers be washed previously, because the strength of mercuric chloride would not be reduced more than 20%, viz., 5.7% average per treatment (Table 3) in wooden vessels. Plummer and Bonde (9) obtained 97% rhizoctonia control by the long soak process in .78/1000 mercuric chloride solution.

The acidulated treatment may be used to advantage, if the standard long soak be considered too long, troublesome and expensive. In a wooden treatment vessel, 20 successive lots of unwashed tubers were treated without the need of testing and adjusting the mercuric chloride solution for volume and strength; the strength of mercuric chloride was depleted less than 10% and that of acetic acid only about 4% (Table 5). It is reasonable to believe that the solution might be used effectively for many more times until about 20% of the mercuric chloride is lost. At any rate, the partially exhausted acidulated solution need not be discarded; it can easily be restored to the original strength (4, 5), and used to treat further successive lots of seed. If the tubers were washed before treating, it is estimated that as many as 40 to 50 successive lots of seed potatoes might possibly

be disinfected by the 10-minute soak in acidulated solutions without the need of adjustment. This assumption is made on the fact that Plummer and Bonde (9) obtained 89% rhizoctonia control of unwashed tubers treated 5 minutes in acidulated solutions of mercuric chloride reduced to about 1.85 : 1000. Accordingly, the maximum number of successive lot disinfections, of washed and unwashed seed tubers by the 10-minute soak in acidulated solutions, is a problem which requires investigation by the plant pathologists.

It should be borne in mind that sacks, crates and soil are the chief offenders in reducing mercuric chloride of seed potato disinfection solutions (6). Accordingly, the practice of using sacks and crates in the process should be discontinued; as much soil and refuse as possible should be kept out of the solution, whether acidified or not; sacks, containing seed to be treated, should not be emptied directly into the disinfection solution on account of the soil and refuse content.

The treating of seed in the fall or winter, or 30 days before planting, appears to offer the best insurance for increased yields in dry seasons. Tuber injury may be prevented by thoroughly drying the seed before storing in containers. No tuber injury resulted from any of the treatments of these experiments.

SUMMARY

For the control of tuber-borne diseases, by treating washed potatoes for 90 minutes in 1 : 1000 mercuric chloride solution, it was possible to control the strength of mercuric chloride in successive lot treatments by the authors' simple method of testing and adjusting; 9 successive lots of tubers were treated by the repeated use of the original solution; the loss of mercuric chloride averaged less than 6% per treatment.

For those who consider the standard treatment too long and expensive and the matter of strength-control too troublesome, the alternative acidulated treatment offers advantages which should meet the popular demand. The presence of acetic acid prevented the rapid depletion of mercuric chloride, which occurred in non-acidulated solutions. Twenty successive lots of unwashed potatoes were treated in a wooden vessel, containing 2 grams mercuric chloride and 16.7 ml. glacial acetic acid per litre, without need of adjustment of any kind. At the end of the experiment, a total of less than 10% mercuric chloride and 5% acetic acid was lost.

Some advantages of the acidulated treatment, compared to the "non-acidulated long-soak", are as follows: 20 or more successive treatments can be made in suitable wooden vessels without adjustment of solution; only 10 minutes are required instead of 90; the tubers need not be washed; acidulation with acetic acid is not injurious to tubers, human skin or clothing; and a considerable saving in labour and material costs is possible.

It should be remembered, for effective control of tuber-borne diseases, that sacks, crates or hampers and as much soil and refuse as possible, should be kept out of the corrosive sublimate solution, whether acidified or not.

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PRESERVATIVES FOR FARM FENCE POSTS

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The maintenance of serviceable fences on farm and ranch lands in the Prairie Provinces of Canada is one of the unavoidable expenses of operators of such lands. Durable woods for this purpose such as round and split cedar and tamarack have become extremely scarce, and are now practically unobtainable. This situation has compelled the general use of less durable posts of native and introduced species of trees.

On the plains it is becoming more difficult every year to obtain post material of any description. A generally drier soil and less precipitation than elsewhere, however, tends to retard the process of post decay, so that untreated fence posts have a service life somewhat longer than under conditions more favourable for the development of decay-producing fungi.

At the Dominion Forest Nursery Station, Indian Head, Saskatchewan, widely known as the source of trees for shelter-belt and woodlot planting, studies in testing materials for preserving home grown fence posts have been carried on for many years. Methods of treatment are of practical application on any farm.

The more commonly known wood preservatives creosote, zinc chloride and copper sulphate (bluestone) have been used in these tests. Over 800 treated and untreated posts of different tree species locally grown have been under test to observe their durability. An attempt was made to ascertain the amount of preservative and time of treatment necessary for maximum post durability. As would be expected these vary with the different species, and are also influenced by the conditions where the posts are permanently set out.

It has been established that superficial treatment of posts such as dipping for a few minutes or applying the preservative with a brush is not effective in preventing decay. Posts treated by these methods do not last appreciably longer than untreated posts. They are therefore not considered useful.

UNTREATED POSTS

The durability of untreated posts is governed by the period of seasoning before being set out. Slow seasoning is very important and desirable. The time of cutting the posts also affects future durability. Winter is the best time to cut posts as the seasoning process is then well advanced before decay-producing fungi become active in summer.

Untreated posts if thoroughly seasoned before being placed in the ground will last years longer than posts of partly seasoned or green cut wood. The recent drought decade also prolonged the service life of prairie

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farm fence posts, which under normal weather conditions, would have required replacing in that period. With a return of normal moisture conditions a very heavy demand for new fence posts may be expected.

TABLE 1.—DURABILITY OF UNTREATED POSTS IN WELL-DRAINED, UPLAND CLAY LOAM*

Species	Range of durability	Average durability
	years	years
Russian poplar	12 to 18	15.5
Aspen poplar	11 to 16	14.0
Willow (acute leaf)	8 to 17	13.5
Maple (box elder)	9 to 16	11.5
White birch	7 to 13	9.5
Cottonwood	7 to 9	8.0
Siberian larch	7 to 18	14.5
Tamarack	9 to 17	14.0
European larch	8 to 12	10.5
Scots pine	8 to 12	10.0

* Records summarized after 18 years—1943.

From figures presented in Table 1 it will be seen that the average durability of Russian poplar, aspen poplar and acute willow is equal to that of Siberian larch, tamarack, and slightly longer than that of European larch and Scots pine.

The record of untreated Russian poplar posts is of particular interest. Being a fast-growing variety under prairie conditions post size wood can be grown in from 7 to 10 years. It responds readily to preservative treatment as will be seen in Table 2. Treatment with a satisfactory preservative may be expected at least to double the service life of Russian poplar posts.

TREATED POSTS

Materials used as preservatives of fence posts in tests begun at Indian Head in 1926 were, creosote, zinc chloride, creozol, and copper sulphate (bluestone). For all treatments except bluestone posts were peeled and seasoned prior to treatment. Posts used were an average length of 7 feet and varied in diameter from 3 to 5½ inches. The butts were treated to a height of 30 inches.

Creosote

Various methods of treating posts with creosote were outlined, namely:

Treatment A. Posts set upright in an open iron tank of creosote maintained at a temperature of 200° to 230° F. for 20 minutes.

Treatment B. Posts dipped in hot creosote for 2 or 3 minutes.

Treatment C. Posts kept in a tank of creosote maintained at a temperature of 200° to 230° F. for 1 hour, then left to cool in the creosote for 10 hours.

Treatment D. Check, posts untreated.

TABLE 2—DURABILITY OF CREOSOTE-TREATED POSTS IN WELL-DRAINED, UPLAND CLAY LOAM*

Species	Treatments							
	A (96 posts)		B (96 posts)		C (48 posts)		D (48 posts)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Russian poplar	62.5	37.5	37.5	62.5	100	—	25	75
Aspen poplar	62.5	37.5	37.5	62.5	100	—	—	100
Willow	87.5	12.5	37.5	62.5	100	—	25	75
Maple	62.5	37.5	50.0	50.0	100	—	—	100
White birch	25.0	75.0	12.5	87.5	100	—	—	100
Cottonwood	75.0	25.0	12.5	87.5	100	—	—	100
Siberian larch (3)	50.0	50.0	75.0	25.0	50	50	50	50
Tamarack	75.0	25.0	50.0	50.0	100	—	—	100
European larch	50.0	50.0	50.0	50.0	100	—	—	100
Scots pine	25.0	75.0	12.5	87.5	100	—	—	100
Average	57.5	42.5	37.5	62.5	95	5	10	90

* Records in per cent summarized after 18 years—1943.
† (1) Posts still sound (2) posts decayed (3) no absorption of creosote.

The most significant observation which may be made from the data presented in Table 2 concerns the effectiveness of creosote treatment when time is allowed to permit the oil to penetrate the wood tissue (treatment C). With the exception of Siberian larch by which there was apparently no absorption of preservative, no losses of posts have occurred in any of the species tested, when given treatment C.

"Check" posts (treatment D) show a directly opposite result. Treatment A on the average, was about 60% as effective as treatment C in prolonging the service life of fence posts, while treatment B was about 38% as effective as treatment C.

Zinc Chloride

Zinc chloride, like copper sulphate (bluestone), is a water-soluble salt, but the strength of the solution must be carefully regulated. A solution of greater concentration than 5% (20 lb. in 40 gallons of water) is likely to weaken the strength of the wood.

For this treatment the solution was maintained at a temperature of 190° to 200° F. for one-half to one hour. Besides being left in the solution while it was heated the posts were left to cool in it for 36 hours. Sixty-seven aspen poplar posts were used for the zinc chloride treatment. The average diameter of these posts at ground line was 4½ inches.

"Survival" of posts in 17 years from this treatment was 88%. Comparable untreated posts had all decayed in 10 years. Painting *zinc* chloride on the butts of aspen posts was not effective in lengthening their durability.

Creozol

The formula for this preservative is not known. It is a preparation known as Coderre's Special, having been developed by Mr. Coderre, formerly in charge of wood preservation, Dominion Forest Products Laboratory, Montreal, Canada.

Treatment consisted of setting the aspen poplar posts in the cold liquid in an open tank to a depth of 30 inches for 12 hours.

In this treatment 29 of a total of 82 posts treated showed no absorption of preservative; they weighed exactly the same after treatment as before. This also occurs with "close" grained woods with other treatments.

The remainder of the posts used in this treatment showed good absorption of preservative liquid. Strangely enough those which absorbed the greatest amount of preservative lasted only from 7 to 11 years, while a number of posts which absorbed the least amount of preservative were still sound after 16 years.

One explanation of this result is that the higher concentration of Coderre's Special weakened the strength of the wood.

From this treatment the average durability of posts was 11 years. "Survival" of posts treated with Coderre's Special (Creozol) in 16 years was 13.4%. Half of the posts which were sound after 16 years absorbed practically no preservative.

Copper Sulphate (Bluestone)

Bluestone treated posts have not been tested for more than 7 or 8 years. Posts treated with this preservative are still sound.

Tests of bluestone as a post preservative have been conducted at other points in the Prairie Provinces. From these tests it is safe to say that the effectiveness of bluestone in prolonging the life of fence posts has been adequately proven.

In a circular *The Bluestone Treatment for Poplar Posts*, published by the Dominion Range Experimental Station, Manyberries, Alta., the following statements are made:

> "Bluestoned poplar on this Station after being in the ground 10 to 12 years, are just as sound as the day they were put in. Untreated poplars have rotted off in from 2 to 4 years. Cases are known in this locality of ranch fences built with bluestoned poplars in 1903 having over 70% of the original posts still in service in 1938."

Tests of bluestone as a post preservative are also being made at the Dominion Experimental Station, Scott, Sask.

Posts can be treated quickly and economically with bluestone. A saturated solution containing from 2½ to 3 pounds of bluestone per gallon of cold water, is recommended. Because this solution corrodes metal it must be prepared in a wooden container.

Only green or unseasoned posts respond readily to bluestone treatment. The treatment consists of placing the bottom ends of posts in the solution to a depth of 18 to 36 inches. Due to loss of moisture at the top by transpiration the solution quickly permeates the cells throughout the length of the posts. As moisture is given off bluestone solution is taken up to replace it.

Before the posts are placed in the solution the portion which will be in the ground is peeled completely. So that the upward movement of the bluestone solution may be watched it is wise to peel a strip a few inches

wide along one side of each post. When the solution is seen to have reached the top the treatment may be considered completed.

In warm spring weather, treatment outdoors may be completed in 12 hours. Where a number of posts are to be treated water and bluestone must be added as required. At the Dominion Experimental Station, Scott, Sask., posts of an average top diameter of 5½ inches absorbed on the average 20 ounces of bluestone solution.

When treated posts are piled to season some are likely to split. This does not seem to decrease greatly the strength of the posts provided the solution penetrated beyond the sap wood to the pith or heartwood. This is especially necessary for the end of the post which goes into the ground.

Tamarack—Untreated

Tamarack posts in this test were distinct from those included in Table 1. The former were part of a specific test planting while those referred to here form part of the supports for the overhead irrigation line. Tamarack ranks among the strongest of soft wood species, being close grained, hard and durable. Like many woods of a hard nature tamarack does not readily absorb preservatives in the open tank method of treatment even when given a prolonged treatment.

As is true of cedar, tamarack is very scarce, and available supplies for posts fall far short of the demand. Untreated tamarack posts, when properly seasoned, almost equal cedar in durability.

Ninety-one untreated tamarack posts produced at Indian Head Forest Nursery Station have been under test for 16 years. The average diameter of the posts was 3½ to 4 inches.

After 16 years, 75% of them are perfectly sound. Between the ninth and sixteenth years 25% became unserviceable. The probable average ***minimum*** durability of untreated tamarack posts of this size would therefore be about 11 years.

Cedar

Untreated cedar has a high durability rating among woods used for fence posts; 114 round untreated cedar posts of an average top diameter of 4 inches have been tested at Indian Head Forest Nursery Station (supports for overhead irrigation system).

After 16 years, 89% of these posts are still sound without evidence of decay. The 11% which have become unserviceable at the ground line still possess good heart wood which would keep the posts in service several years longer if the pull and strain on them was not too great. Posts considered unserviceable were eliminated from the test between the ninth and sixteenth years.

Untreated cedar posts of the size used in this experiment are therefore considered to have an average ***minimum*** durability of 12 years.

SUMMARY

The average durability of untreated fence posts of various tree species has been determined (Table 1). Untreated posts that have been well seasoned before being placed in the ground are believed to have greater durability than posts cut green and placed in the ground without seasoning.

Various treatments in the use of creosote as a preservative were tested. Greatest durability resulted from setting posts to a depth of 30 inches in creosote heated to a temperature of 200° to 230° F. for 1 hour and allowing them to cool off in the creosote for 10 hours (Treatment C, Table 2).

The "survival" of posts treated in a 5% solution of zinc chloride heated to 190° to 200° F. for one-half to one hour, and allowed to cool in the solution for 36 hours was slightly less than the "survival" from the best creosote treatment (treatment C).

FIGURE 1. Posts of different tree species cut, peeled, and piled for seasoning before Creosote preservative treatment. F.N.S. Indian Head, Sask.

Creozol proved to have much less value than creosote as a post preservative.

Bluestone, when used as a saturated solution on green cut poplar posts would seem to increase greatly their durability. This treatment is simple and economical.

The average durability of untreated tamarack and cedar posts is slightly less than that of posts of different species subjected to the most effective chemical treatments.

Tests reported on in this paper are continuing. The object is to ascertain for the benefit of shelterbelt and woodlot planters in the Prairie Provinces the probable durability of home-grown fencing material.

An attempt has been made to indicate the likely difference in the service life of treated and untreated posts of various tree species.

Farmers, with established shelterbelts on farms throughout the Prairie Provinces have access to a great deal of fence post material. A gradual thinning of these shelterbelts should solve in large measure the problem of new and replacement fence posts.

FIGURE 2. Oil circulation pipes over fire pit and connected with Creosote container. F.N.S. Indian Head, Sask.

FIGURE 3. View of testing ground in 1943 after 18 years; 50% of posts still sound. F.N.S. Indian Head, Sask.

MICROBIOLOGICAL ASPECTS OF EGG POWDER[1]

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Although small quantities of spray-dried egg powder had previously been produced in Canada, the decision of the British Ministry of Food early in 1942 that all eggs should subsequently go forward in powder form created tremendous problems overnight. The production of millions of pounds of egg powder of a quality high enough to make an acceptable dish of scrambled eggs for the British consumer some months later meant that a great deal had to be learned regarding the entire process. That remarkable progress has been made in quality improvement is evident from the very high reputation enjoyed by Canadian egg powder in Britain; much of this can be attributed to the excellent co-operation between the Special Products Board and its technical advisers on the one hand, and the drying plant operators on the other.

Anyone who has smelt a rotten or musty egg should appreciate what bacterial growth can do to egg quality. However, eggs used for drying are first candled and graded; then when broken out they are again carefully inspected for abnormal appearance, and smelt to detect any off-odour. With the high quality of eggs being broken for drying in Canada (84% Grade A, 16% Grade B in 1943) the initial product contains very few bacteria (6, 7, 11, 12, 15), but in a small proportion, mostly soiled eggs, bacteria have penetrated the shell. Given favourable temperature conditions these organisms will grow rapidly and cause spoilage, hence the need for temperatures near their freezing point if eggs ear to be held for any extended period. The broken-out eggs, commonly referred to as melange, generally contain relatively few bacteria (8); if the melange is handled in properly sanitized equipment and kept sufficiently cold before drying, the resultant powder should show a very low count. (The drying process itself may destroy as high as 99.5% of the organisms in the melange (8), although the average reduction is much less than this (2, 4).) Unfortunately, plant sanitation and practices are not always what they should be; when conditions are not right, higher counts on the powder may be anticipated. Consequently, as a means of checking on plant practices, limits for total viable count and for *E. coli* were incorporated in the specifications for the 1943 contract.

OFFICIAL BACTERIOLOGICAL CONTROL OF CANADIAN EGG POWDER

Standards

Since little was known regarding the proper limits for bacterial content in egg powder, the standards finally agreed upon were a compromise between the views of the British Ministry of Food, the Special Products Board and its technical advisers, and the driers. They were as follows:

[1] Contribution No. 182 (Journal Series) from the Division of Bacteriology and Dairy Research, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Associate Bacteriologist.

Grade A Powder (prime powder for use in fresh egg dishes); total viable count after 48 hours incubation at 37° C. shall not exceed 500,000 per gram, with *E. coli* absent from 1/100 gram.

Grade B Powder (residual fractions, for baking purposes only); no limit for viable count, but *E. coli* absent from 1/1000 gram.

A tolerance of one car in four exceeding either the viable count or *E. coli* limits without the penalty of degrading[3] was agreed upon for Grade A powder, provided the presence of Salmonella types (other than *S. pullorum*), hemolytic streptococci and coagulase positive staphylococci could not be demonstrated. (This proviso regarding the absence of certain pathogenic types was suggested by the British Ministry of Food, who suspected that dried eggs might have been responsible for outbreaks of Salmonella food poisoning in Britain. However, in the absence of convincing evidence that such suspicion is justified, the reference to pathogens has been dropped from the 1944 specifications.)

METHODS

Simplified Technique

While certain bacteriological studies on dried eggs had been carried out by the Division of Applied Biology, National Research Council (4, 16), the official control work became the responsibility of the Division of Bacteriology and Dairy Research, Science Service, Department of Agriculture, on January 1, 1943. In addition to this routine work, investigations on various points, both in the drying plants and in the laboratory, have been carried on. Work was immediately commenced on the development of methods of analysis which would be better suited to routine control than were the research methods previously used (16). To this end, the standard agar medium employed in official milk control (1) was substituted for proteose peptone-tryptone agar, shaking of the primary dilution of powder with broken glass was substituted for the more laborious grinding with sand, while the number of tubes of Brilliant Green lactose bile broth used in the detection of *E. coli* was reduced from 20 or more to 5 per sample. In the latter connection, time was saved by the use of a single long copper cap covering the tops of all 5 tubes, in place of individual cotton stoppers. A detailed description of the official methods of analysis appears in Appendix A.

Preparation of Sample

Plating out from several replicate portions of certain samples soon revealed the need for a more adequate technique of mixing the sample. The official carlot sample, taken by the inspector at the plant, is a composite of portions taken from 80 or 90 packages. Since the bacteria count often varies greatly during a single day's drying operations (8), the composite sample may contain portions of powder of widely different bacterial content. After experimenting with a number of methods, the one finally adopted consisted in running the powder twice through a sterilized household flour sifter with a 4-armed rotating beater. Replicate portions of powder so treated showed a more satisfactory degree of uniformity in counts.

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[3] Degrading of a carlot of powder from Grade A to B meant a reduction of 5c. per pound in the drying charge paid the drier—approximately $3,000 per carlot.

A Simple Test for Plant Control Work

Since the driers were to be severely penalized financially whenever a carlot of otherwise satisfactory powder failed to meet the bacteriological standards for Grade A powder, consideration was given to the possibility of developing a simple plant test whereby the drier could check his product from day to day to assure himself that his counts were not too high. To this end, the methylene blue and resazurin reduction tests (1), widely used in milk control, were adapted for use with egg powder. The powder was reconstituted by adding 2.5 gm. to 7.5 ml. of sterile physiological saline in a $\frac{5}{8}'' \times 6''$ test tube containing broken glass, stoppering and shaking for a minute or two until the powder had gone into suspension. The reconstituted powder then had approximately the same moisture content as the melange before drying. The usual dye concentrations (1 : 300,000 methylene blue or 1 : 200,000 resazurin) were employed, and tubes were incubated at 37° C.

Because of the wide differences in the intrinsic colour of reconstituted powder from one sample to another, considerable difficulty arose in determining the degree of colour change. This was particularly true with resazurin. Consequently it was decided to concentrate on methylene blue, using complete reduction as the end-point. The comparative plate counts and methylene blue reduction times for 80 samples of powder tested between November 1942 and February 1943 are shown in Figure 1. It will be observed that the average reduction time for a given plate count is considerably longer than for an equivalent bacterial content in milk. This means that incubation would have to be continued for an inconveniently long time in order to detect all samples with plate counts in excess of 500,000 per gram.

Since this work was conducted, Scott and Gillespie (14) have described the use of the resazurin test as an indicator of quality in egg pulp in Australia. The test was modified by using a stronger concentration of dye (1 : 120,000), a lower incubation temperature (30° C.) and a pink end-point. The results showed a close correlation with the plate count on beef extract agar after 3 days at 25° C. However, in dealing with the quality of melange usually encountered in Canada, the test would be of limited value because of the long incubation period required. (A plate count of 500,000 per ml. was equivalent to an average reduction time of approximately 6 hours in their studies.)

A more promising method for plant work is the Burri Slant Method (1, 7). In this method a calibrated loop is employed to pick up a very small portion of the liquid (approximately 1/2,000 gram); this is then distributed as evenly as possible over the dried surface of a tryptone glucose agar slant, and the tube incubated at a suitable temperature. This method has proven exceedingly useful in connection with plant sanitation studies, and much wider use will be made of it in 1944.

Direct Microscopic Count Method

While the plate count method has been of distinct value in directing attention to faulty conditions, it was noticed that the powder from certain plants gave much lower counts than would be expected on the basis of sanitation surveys. It is generally agreed that the plate count of dried milk solids is not a reliable indication of the quality of the raw milk used, since the process of manufacture and subsequent storage have a direct bearing upon the extent to which the bacteria survive. Information at hand suggests that the same holds true for dried whole egg (4, 8). In the dried milk field the direct microscopic method furnishes valuable information concerning the previous history of the product (10), and it seemed logical to assume that this also holds true for dried eggs. Bartram (2) has recently reported that this is the case. Consequently, starting July 28, 1943, it was decided to make direct microscopic counts concurrently with plate counts.

The results of these comparative studies, which are being reported elsewhere (9), confirm the opinion that the direct microscopic count does afford a better indication of the care given the melange prior to drying. A direct microscopic count limit of 2,000,000 per gram is therefore being incorporated in the 1944 specifications for Canadian Grade A powder.

Coliform Organisms and E. Coli

The determination of coliform organisms or of *E. coli* in egg powder has not been found particularly helpful. In drawing up the specifications it was expected that there would be a fairly close parallel between total counts and the presence of these types of bacteria, as has been reported for frozen eggs (13). The data presented in Table 1 indicate that this is frequently not the case; a high level of coliforms may accompany a low count, or a low level of coliforms a high count. Furthermore, there seemed to be little agreement between the results of coliform tests and of plant sanitation surveys in several plants. In consequence, the determination of coliform organisms and *E. coli* in Grade A powder has been dropped for 1944.

Résumé of Results of 1943 Operations

That Canadian driers, with few exceptions, have done a fairly satisfactory job from a bacteriological standpoint is indicated by the summarized distribution of plate counts in Table 2. Only 10 (4.25%) of the 235 cars of Grade A powder exceeded the limit of 500,000 per gram. Of these 10 high counts, 3 could be attributed largely to slow freezing of melange stored for subsequent drying, with consequent bacterial development in the central core of the block; 2 others were due to the growth of a heat-resistant streptococcus in a tubular pre-heater, while only 2 could definitely be attributed to faulty care of equipment. Of the 3 remaining 2 (from Plant H) appeared to result from a peculiarity in the construction of the drier.

The high counts due to the use of a pre-heater are of interest. This plant (G) had used the same tubular pre-heater since commencing operations in August 1942 with a satisfactorily low level of counts. However, during February 1943 a powder cooling system was installed, whereby the powder was cooled to 80° F. or lower as it left the drying chamber. As Gibbons and Fulton (4) have reported, prompt cooling of the powder means a significantly higher number of organisms surviving. This, together with a gradual increase in the length of the day's run as production increased, resulted in a markedly higher level of counts. Studies at the plant showed that counts near the start of the day's drying were quite low (14,000 to 41,000 per gram on 4 days) while at the end of the 19-hour run counts as high as 24,000,000 per gram were obtained. This enormous increase was found to be due to the growth of bacteria in portions of the melange adhering to the rubber gaskets and to the walls of the tubes, which latter frequently showed serious scoring; the melange came from holding vats at temperatures around 35° F. and was heated to around 80° F. in the tubular heater by water at 120° F. In at least one instance, the material remaining in the tubes at the end of the run was so acid it had coagulated. The organism responsible for the high counts was found to be a streptococcus closely resembling *S. thermophilus*. It produced pin-point colonies on tryptone glucose agar, and died off very rapidly in the powder. One sample gave an initial count of 2,700,000 per gram, yet after 12 days' storage at 40° F. the count had fallen to 710,000. Upon elimination of the pre-heater the count fell abruptly, the highest at the end of the next 3 days' runs being 7,000 per gram.

Effect of Temperatures in Transit upon Bacterial Content of Egg Powder

As was previously mentioned, the viable count of bacteria in egg powder is markedly affected by the temperature to which it is exposed after leaving the drying chamber. In order to determine what bacteriological changes might be brought about in official carlot samples en route from the plants to the laboratory in Ottawa, two series of experiments were carried out. In the first experiment, samples of powder were taken directly from the sifter at a local plant on 5 successive days; in the second, similarly taken samples were shipped by express from each of 6 other drying plants. In each case the sample, after thorough mixing, was subdivided into a number of portions, each of which was exposed to a definite temperature for a definite period. Each sub-sample was then analyzed bacteriologically and the results compared with those from the initial analysis. From the average values, shown in Table 3, it appears that at 40° F. the bacteria counts showed no appreciable change even after 5 days; at 70° a moderate decline was noted after 2 days, being much more evident in the higher count samples, while at 86° to 90° a sharp reduction was noted, this being evident even after 1 day. Coliform organisms and *E. coli* appeared to die off more rapidly than the general flora at all three temperatures, the decrease being particularly pronounced at the higher temperatures.

In order to keep such changes at a minimum, consideration was first given to the use of dry ice in the shipping container. However, this had to be dropped as dry ice was not available at several points where eggs were

being dried. Instead, it was decided to have the samples cooled as thoroughly as possible before shipment. Samples from Western Canada were to be sent by air express, those from Eastern Canada by railway express. In this way all samples should reach the laboratory within 24 hours, with little or no change in their bacterial content.

Bacterial Flora of Melange and Powder

Some studies were conducted upon the flora of melange and of powder. Approximately 100 colonies from each of a series of plates prepared from samples of powder from 7 plants, and of melange from 1 plant, were fished into litmus milk and incubated at around 86° F. (30° C.) for 5 days. Smears were made from each tube, stained according to Gram's method and examined microscopically. While the flora of the single sample of melange comprised a variety of types, Gram negative rods predominated; in the powder samples on the other hand, a streptococcus which produced slight acid but failed to coagulate litmus milk was the preponderant type; often comprising over 90% of the colonies fished.

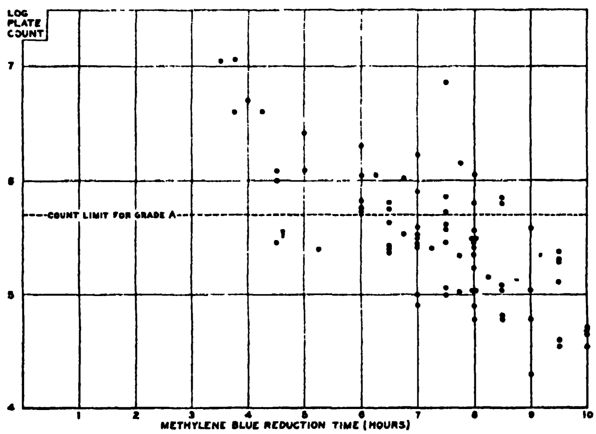

FIGURE 1. Comparative methylene blue reduction times and plate counts on 80 samples of dried egg.

SUMMARY AND CONCLUSIONS

The standards and procedure employed in the bacteriological control of Canadian dried eggs for export to Britain are described, together with some of the results for 1943. In 1943, out of a total of 235 carlots of Grade A powder, 95.75% gave plate counts of under 500,000 per gram.

As a simple plant test for bacterial content of melange, the Burri slant method has been found most useful. Dye reduction tests were not so satisfactory because of end-point difficulties and the long incubation periods required.

The direct microscopic count was found to reveal the past history of the product more satisfactorily than did the plate count, coliform or *E. coli* test.

The possible changes in bacterial content resulting from exposure of samples to various temperatures en route to the official control laboratory were investigated and arrangements made to minimize such changes.

Studies on the flora of melange and powder revealed that the Gram negative rods which predominated in the former were generally replaced by a weak acid producing streptococcus in the powder.

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TABLE 1.—RELATION BETWEEN BACTERIA COUNTS, COLIFORM AND *E. coli* CONTENT OF CANADIAN GRADE A DRIED EGGS

Sample	Bacteria count (thousands per gram)		No. of tubes* Positive for	
	Viable	Direct microscopic	Coliform organisms	*E. coli*
A	21		3/5	3/5
B	12	220	20/20	19/20
C	41	880	15/15	11/15
D	3		12/15	10/15
E	5		11/25	8/25
F	21	880	10/20	9/20
G	55	550	15/15	10/15
H	26		2/5	2/5
I	15		5/5	2/5
J	38		8/10	7/10
K	470		0/5	
L	1,300		1/5	1/5
M	630		5/25	3/25
N	2,000		6/25	6/25
N	580		0/5	
O	1,100	12,000	0/10	
P	2,000	35,000	1/5	1/5
Q	2,000		6/25	6/25
R	1,200		2/20	2/20
S	1,100	4,100	0/5	

* Inoculated with 1/100 gm. of powder.

TABLE 2.—DISTRIBUTION OF VIABLE COUNTS ON DRIED EGGS. 1943.

Grade A		Viable counts (thousands per gram)					
Plant	No. of carlot samples	<10	10–25	26–100	101–500	501–1,000	>1,000
A	20	1	14	4	1		
B	21	1	1	9	8	0	2
C	29	2	1	10	14	1	1
D	55	19	13	21	2		
E	11		2	1	8		
F	15	1	8	5	1		
G	49	15	4	16	11	1	2
H	22				20	2	
I	13	1	1	4	6		1
Totals	235	40	44	70	71	4	6
Percentage		17.0	18.7	29.8	30.2	1.7	2.6
Grade B							
A	6		1	3	2		
B	14	1	1	5	5	1	1
C	19	0	1	9	7	0	2
D	12	4	4	3	1		
E	5			3	2		
F							
G	6		1	4			1
H	5				1	0	4
I	3	1	0	2			
Totals	70	6	8	29	18	1	8
Percentage		8.6	11.4	41.4	25.7	1.5	11.4

TABLE 3.—EFFECT OF TEMPERATURE ON BACTERIAL CONTENT OF WHOLE EGG POWDER

Series I (Averages of 5 samples)	Days held	Temperature (°F.)		
		40°	70°	86°
Plate count	0	76,400	76,400	76,400
	2	84,300	55,900	30,900
	5	79,000	50,000	7,680
Coliform organisms*	0	40.4	40.4	40.4
	2	60.2	48.8	5.2
	5	53.4	20.0	0.0
*E. coli**	0	20.6	20.6	20.6
	2	56.0	13.1	0.8
	5	18.4	1.7	0.0
Series II (Averages of 6 samples)	**Days held**	**40°**	**70°**	**90°**
Plate count	0	98,100	98,100	98,100
	1	100,000	90,900	52,600
	2	117,000	70,000	29,000
Coliform organisms*	0	8.4	8.4	8.4
	1	5.1	2.2	0.6
	2	4.2	1.3	0.3
*E. coli**	0	1.8	1.8	1 8
	1	2.9	1.8	0.3
	2	1.8	0.7	0.0

* Most probable number calculated from inoculation of 5 tubes with 0.1 gm. and 5 tubes with 0.01 gm. of powder.

APPENDIX A.

OFFICIAL METHODS FOR BACTERIOLOGICAL ANALYSIS OF CANADIAN WHOLE EGG POWDERS

(1) *Preparation of Sample*

Studies have shown that certain samples vary widely in count from portion to portion. Thorough mixing of the sample is therefore essential. Running the powder at least twice through a suitable type of flour sifter (which has previously been sterilized) has been found to give good results. Where the same sample is to be used for chemical analysis, care should be taken that it is not unduly exposed to the air because of the ease with which it picks up moisture from the atmosphere.

(2) *Reconstitution of Powder*

A 1 : 10 dilution is prepared by weighing out 11 grams of the thoroughly mixed sample into a sterile wide-mouthed jar or flask of approximately 200 ml. capacity containing a spoonful of glass beads. The contents of a dilution bottle containing 99 ml. of sterile physiological saline solution (0.85% NaCl in distilled water) are then poured into the jar or flask and the contents shaken vigorously until a uniform suspension is obtained, usually within a minute. The dilution should be allowed to stand for several minutes until the air bubbles have risen to the surface before preparing further dilutions.

If desired, the 1 : 10 dilution may be prepared by using 10 grams of powder and 90 ml. of saline.

Further dilutions are prepared by introducing 1, 10, or 11 ml. portions of the 1 : 10 dilution into dilution blanks containing appropriate amounts of sterile saline solution.

(3) *Escherichia coli Test*

From the 1 : 100 dilution five 1-ml. portions are pipetted into a similar number of fermentation tubes containing 2% Brilliant Green bile broth for the *E. coli* presumptive test. A 10-ml. or 11-ml. pipette graduated in 1 ml. is convenient for this purpose. Tubes are incubated at 37° C., and observed at intervals over 48 hours. As soon as gas formation is observed, the liquid in each of such tubes is streaked over the surface of a plate previously poured with eosin-methylene blue agar and allowed to harden. Two such streakings may be made on separate halves of the same plate. The streaked plate is incubated at 37° C. for 18 to 24 hours; the appearance of typical black metallic colonies is regarded as indicative of the presence of *E. coli.*

(4) *Total Viable Bacterial Count*

For total bacterial count, duplicate plates are prepared from both 1 : 1,000 and 1 : 10,000 dilutions. From the 1 : 100 dilution, 0.1-ml. portions may be transferred with aid of a 1.1 or 2.2-ml. pipette to the plates for the 1 : 1,000 dilution, while 1-ml. portions of the 1 : 100 dilution are transferred to a 99-ml. saline dilution bottle to give a dilution of 1 : 10,000. From the latter, 1-ml. portions are pipetted into plates for that dilution. If desired, dilutions may be prepared from the 1 : 100 dilution by introducing 11-ml. quantities into 99 ml. dilution blanks, or 10-ml. into 90 ml. blanks.

Approximately 10 ml. of medium, melted and cooled to 41–42° C., are poured into each plate and mixed with the inoculum within 20 minutes of preparing the 1 : 100 dilution. The medium employed is the standard medium for milk analysis, tryptone glucose extract agar containing 1% skim milk. If desired, the skim milk may be omitted, since it has no appreciable effect upon the count obtained with egg powders. After the medium has hardened, plates are incubated at 37° C. for 48 hours and all colonies counted with the aid of a Quebec colony counter or equivalent device. The average of duplicate plates on the dilution represents the total bacterial count.

Retest of Samples Exceeding Limits for Grade A

Should the total count exceed 500,000 per gram, or should 2 or more of the 5 fermentation tubes contain *E. coli*, a further 11 (or 10) gram sample is taken and the above analysis repeated. An additional 10 tubes containing Brilliant Green bile broth are inoculated with 1 ml. portions of a 1 : 1,000 dilution to ascertain whether the powder exceeds the limit for Grade B (not more than 4 of the 10 tubes to contain *E. coli*). The grade of the powder is then determined on the average of the results from both sets of analyses.

WHEAT STEM SAWFLY IN FLAX[1]

C. W. Farstad[2]

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[Received for publication February 28, 1944]

The wheat stem sawfly (*Cephus cinctus* Nort.) has as its primary hosts wheat and wheat-like grasses. However, in the absence of these plants, others may be selected for oviposition.

In 1942 large acreages of sawfly-infested land were seeded to flax. Many inquiries were made by farmers as to whether or not sawflies would lay their eggs in flax and, if so, would the larvae survive. That year, Mr. Horace Hockett of Shaunavon, Saskatchewan, first brought to the attention of the writer the fact that a sawdust-like deposit which resembled the condition found in sawfly-infested wheat stems could be found in some flax stems. This led to an investigation which definitely established that *C. cinctus* oviposition was quite common in flax. The study was continued throughout 1942 and 1943 to determine to what extent, if any, this insect could survive and mature in flax, and whether or not any economic loss resulted therefrom.

INVESTIGATIONS

Infestation in Relation to Date of Seeding

A general examination of some of the flax fields in southwestern Saskatchewan and southern Alberta indicated that only the early-seeded flax was infested. Dates of seeding were available in some instances and detailed examinations were made in some of these fields. Supplementary

Table 1.—Infestation and date of seeding

Date of seeding	Percentage infestation		
	Swift Current*	Lafleche	Crane Valley
	%	%	%
First week in May	67	75	80
Second week in May	30	—	25
Last week in May	0	0	0

* Replicated plots on Dominion Experimental Station, Swift Current, Saskatchewan.

examinations of early- and late-seeded flax fields scattered throughout the sawfly-infested area of Saskatchewan and Alberta further substantiated the findings given in Table 1.

Effect on the Crop

In some stems almost complete tunnelling was accomplished by the sawfly larva (Figures 1 and 2), the inside pith layer apparently being fed upon. In some instances this layer was completely removed from the underlying xylem, or wood layer.

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[2] Assistant Entomologist.

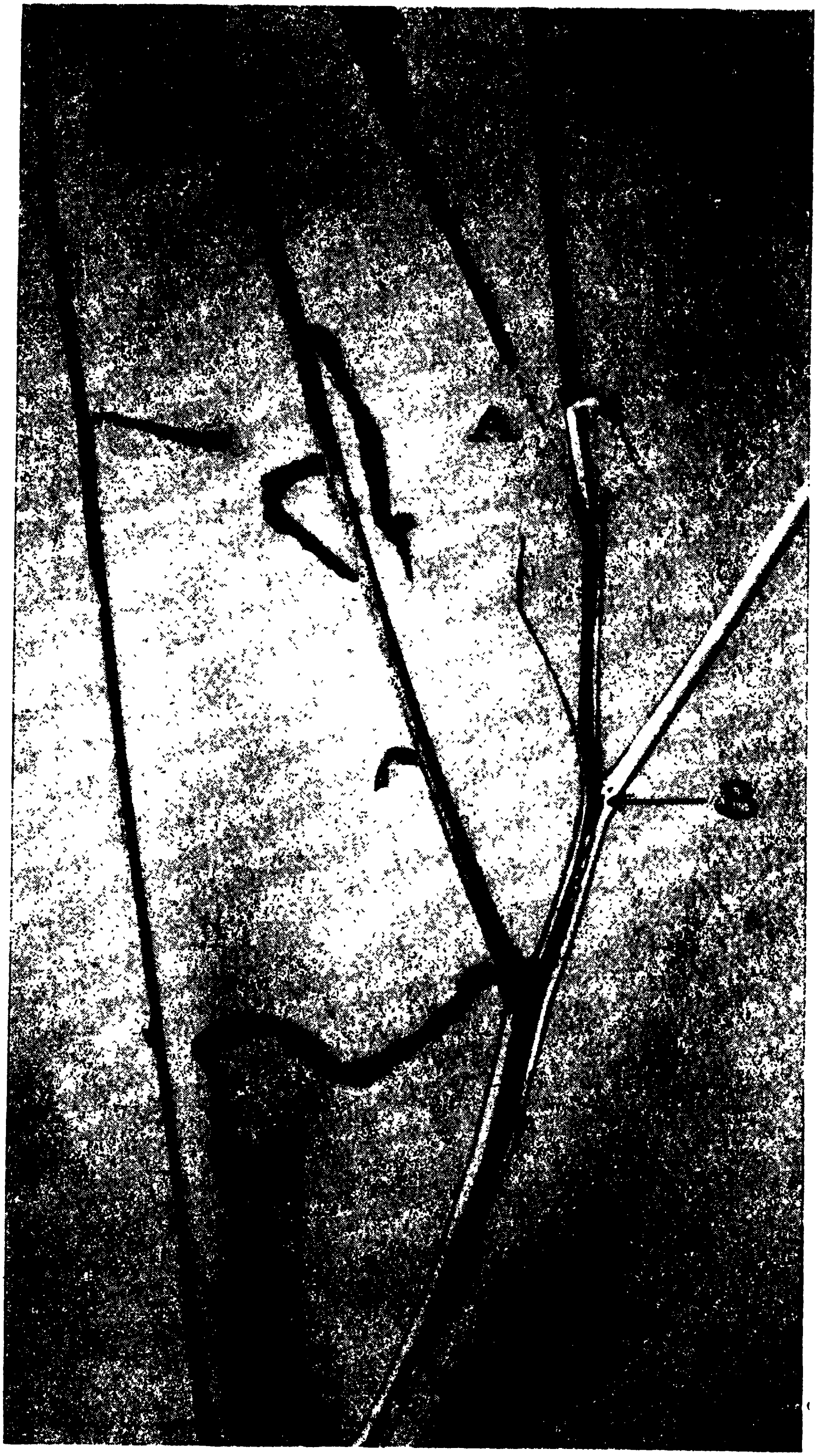

FIGURE 1. Portion of tunnelled flax plant showing severed branch (A) and position of dead larva (B). (Photograph by A. C. Budd, Experimental Station, Swift Current, Sask.)

Detailed examinations of infested stems were made to determine to what extent crop loss resulted from the feeding of the larvae. Where tunnelling of the stem was complete, well developed larvae occasionally attempted to enter small branches with the result that the branch was almost severed from the stem, remaining attached only by a few flax fibres which broke very readily as they dried out and became brittle (Figure 1).

This condition was rare and the resulting loss would be insignificant. The bolls from infested and uninfested plants were threshed by hand and

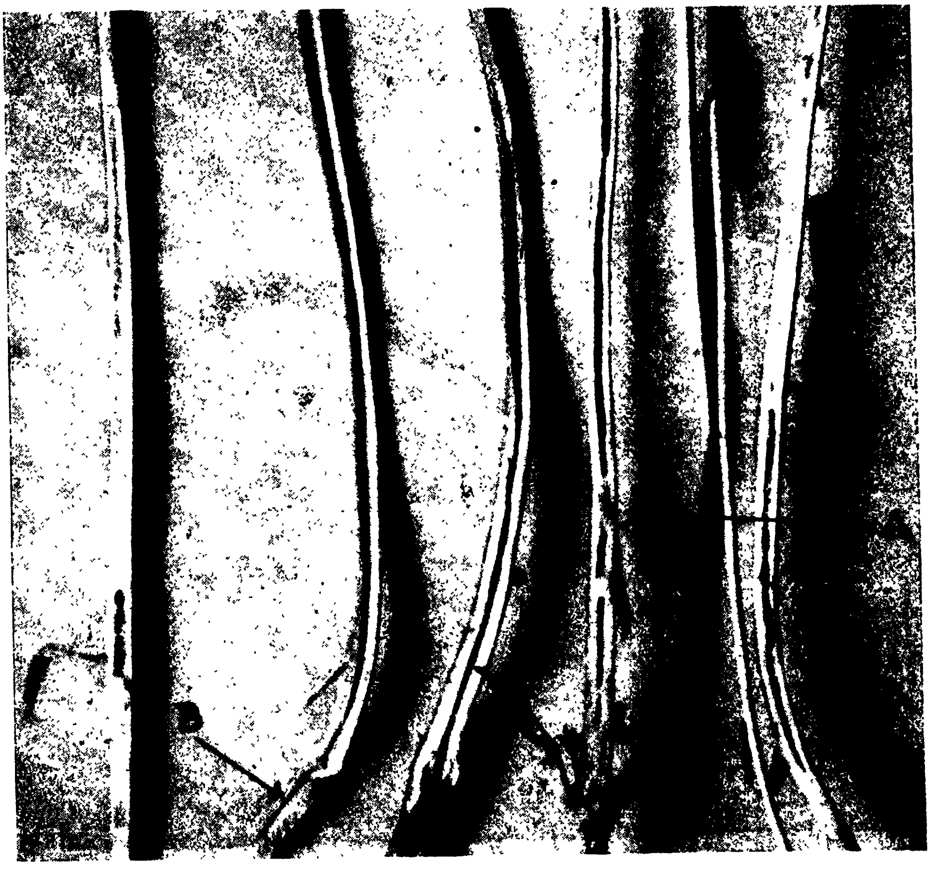

FIGURE 2. Infested flax stems. Living larvae at (A) and tunnelling in completely solid basal portion of plant (B). (Photograph by A. C. Budd, Experimental Station, Swift Current, Sask.)

examined, but there was no visible evidence of shrunken seeds or excessive sterility in the ovules which could be attributed to the damage caused by sawfly feeding.

At Assiniboia and Lafleche, Saskatchewan, in some flax fields which were severely infested, 5 to 10% of the stems on the margins showed a tendency to bend and lodge. At first this was attributed to the deep sawfly feeding pits at the point of breakage. However, closer examination

revealed that the breakage occurred only to stems which had been extensively fed upon by grasshoppers. The epidermis, cortex and the bast fibres had been stripped off, weakening the stem sufficiently to cause lodging. It was the combination of internal feeding by the sawfly larva and external feeding by the grasshoppers at the same general point on the stem, rather than either one working alone, that was responsible. Because of the branching nature of the plant it did not fall to the ground, as is the case with wheat, but was entangled with and supported by adjacent plants so that it could readily be harvested.

In some plants the woody, completely solid basal portion of the plant below the ground surface was partially tunnelled (Figure 2).

Larval Development and Growth

The rate of growth of sawfly larvae in flax is much slower than in wheat. On August 12, 1942, one hundred larvae were collected from each of two adjacent fields of flax and wheat. The stage of development of each larva was determined by measuring the width of the head capsule. Mortality counts were made at the same time. Table 2 summarizes these data.

TABLE 2.—DIFFERENTIAL GROWTH AND MORTALITY IN WHEAT AND FLAX

	Percentage of each instar				Percentage mortality
	2nd	3rd	4th	5th	
	%	%	%	%	%
Wheat	0	7	34.5	58.5	0
Flax	8	23	53.7	15.3	26

In general the larvae in flax were less active than those in wheat. As long as the flax plant remained green and succulent, a proportion of the larvae remained alive. As ripening progressed, mortality increased markedly. At Lafleche, Saskatchewan, 96% of the infested stems contained only dead larvae on September 7, 1942. In later examinations made in fields throughout Saskatchewan and Alberta, during and after harvesting, the mortality was 100%. No living larvae were found.

CONCLUSIONS

As a potential pest of flax, *Cephus cinctus* Nort. appears to be of little importance. A relatively insignificant number of branches may be severed, and in combination with grasshopper feeding some breakage may occur. The value of flax as a crop for ridding a field of its sawfly infestation probably far outweighs the small economic loss that can be directly or indirectly attributed to this insect.

RECORD OF LEPIDOPTERA CAPTURED AT A LIGHT TRAP AT NEW CARLISLE, QUEBEC, IN 1941[1]

J. P. PERRON[2]

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[Received for publication February 9, 1944]

During the course of some entomological investigations on the Gaspe Coast in 1941, a light trap was set up at New Carlisle early in July and was kept in operation until late September. The record of some of the insects taken is presented as a contribution to the knowledge of the fauna of this region.

The light trap, furnished with a bulb of 20 watts, was suspended between 10 and 15 feet above the ground. It was attached to the southern wall of a building and had a full exposure towards the southeast across open fields which had a gentle downward slope about one-quarter of a mile to the sea. The captures at the light were good during most of the summer. The most productive nights yielded from 450 to 500 specimens. As would be expected, warm, calm evenings were the most favourable for insect flight, and collections were always very large under such conditions. The largest captures were made during July, and insects came freely to the light during all of this month and during the first part of August. After that large captures were rare.

The majority of insects collected were Lepidoptera, and very few Coleoptera, Diptera or Hymenoptera were taken. Of these 157 species of Lepidoptera were identified. All identifications of the former were made by Dr. McDunnough and T. N. Freeman of the Systematic Unit of the Division of Entomology. The author is greatly indebted to these gentlemen for their assistance and co-operation. The identifications were made from selected specimens pinned and mounted in the field and brought to Ottawa at the end of the season. Although numerous specimens were taken, many species were undoubtedly overlooked. Particular attention in sorting was given to the noctuids in order to check on the species of cutworms that might be present in the region.

After the list was compiled Mr. Freeman kindly reviewed it and noted that the capture of *Sphinx canadensis* Bdv. was unusual, it being one of our rarest sphingids and occurring only sparsely throughout its range; that *Septis inordinata* Morr. was rare in collections and unusual so far north; and that *Autographa oo* Cram. represents the first Canadian record of this more southern species.

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[2] Agricultural Assistant.

The list of captures is as follows:

SPHINGIDAE

707 *Ceratomia undulosa* Wlk.
725 *Sphinx canadensis* Bvd.
727 *Sphinx kalmiae* A. & S.
739 *Smerinthus jamaicensis* form *geminatus* Say
741 *Paonias excaecata* A. & S.
798a *Celerio gallii* var. *intermedia* Kby.

AMATIDAE

884 *Ctenucha virginica* Charp.

ARCTIIDAE

980 *Halisidota maculata* Harr.
1033 *Apantesis virgo* Linn.
1065 *Diacrisia virginica* Fabr. (?)
1069 *Isia isabella* A. & S.
1070 *Estigmene acrea* Dru.
1070a *Estigmene acrea* form *dubia* Harr.

PHALAENIDAE

1130 *Panthea furcilla* var.
1141 *Raphia frater* Grt.
1148 *Acronicta americana* Harr.
1153 *Acronicta lepusculina* Gn.
1155 *Acronicta innotata* Gn.
1160 *Acronicta grisea* Wlk.
1181 *Acronicta morula* G. & R.
1185 *Acronicta fragilis* Wlk.
1195 *Acronicta retardata* Wlk.
1215 *Acronicta oblinita* A. & S.
1272 *Euxoa* sp. near *detersa* Wlk.
1292 *Euxoa perpolita* Morr.
1297 *Euxoa scandens* Riley
1378 *Euxoa ochrogaster* Gn.
1382 *Euxoa tristicula* Morr.
1382 *Euxoa tristicula* form *nesilens* Sm. (?)
1425 *Agrotis venerabilis* Wlk.
1432 *Agrotis volubilis* Harv.
1435 *Agrotis ypsilon* Rott.
1446 *Feltia herilis* Grt.
1452 *Actebia fennica* Tausch.
1472 *Spaelotis clandestina* Harr.
1475 *Eurois occulta* Linn.
1476 *Eurois astricta* Morr.
1480 *Ochropleura plecta* Linn.
1511 *Graphiphora c-nigrum* Linn.
1512 *Graphiphora smithi* Snell.
1513 *Graphiphora normaniana* Grt.
1517 *Graphiphora oblata* Morr.
1552 *Graphiphora collaris* G. & R.
1569 *Anaplectoides pressus* Grt.
1570 *Anaplectoides prasina* Schiff.
1575 *Cryptocala acadiensis* Beth.
1577 *Eueretagrotis perattenta* Grt.
1661 *Mamestra curialis* Sm.
1663 *Polia nimbosa* Gn.
1669 *Polia purpurissata* Grt.
1673 *Polia subjuncta* G. & R.
1677 *Polia atlantica* Grt.
1683 *Polia legitima* Grt.
1687 *Polia lilacina* Harv.
1687 *Polia lilacina* form *illabefacta* Morr.
1691 *Polia adjuncta* Bdv.
1693 *Polia assimilis* Morr.
1714 *Lacinipolia lustralis* Grt.
1738 *Lacinipolia renigera* Steph.
1744 *Lacinipolia lorea* Gn.
Orthodes sp.
1855 *Orthodes oviduca* Gn.
1871 *Orthodes crenulata* Butl.
1895 *Nephelodes emmedonia* Cram.
1992 *Leucania* sp. probably *insueta* Gn.
1994 *Leucania unipuncta* Haw.
1995 *Leucania* sp. probably *Luteopallens* Sm.
2038 *Cucullia intermedia* Speyer.
2042 *Cucullia postera* Gn.
2215 *Litholomia napaea* Morr.
2241 *Graptolitha lepida* Grt.
2272 *Crino* sp. probably *ducta* Grt.
2312 *Rusina bicolorago* form *ferrugineoides* Gn.
2328 *Septis verbascoides* Gn.
2335 *Septis lignicolora* Gn.
2351 *Septis arctica* Frr.
2353 *Septis alia* form *rorulenta* Sm.
2355 *Septis inordinata* Morr.
2361 *Septis commoda* Wlk.
2365 *Septis finitima* Gn.
2366 *Agroperina lateritia* Hufn.
2368 *Agroperina dubitans* Wlk.
2368a *Agroperina dubitans* form *cogitata* Sm.
2375 *Crymodes devastator* Brace
2423 *Oligia illocata* Wlk.
2424 *Oligia mactata* Gn.
2458 *Apamea velata* Wlk.
2459 *Apamea americana* Speyer.
2474 *Hydroecia micacea* Esp.

PHALAENIDAE—*Concluded*

2479 *Papaipema appassionata* Harv.
2521 *Papaipema frigida* form *thalictri* Lyman.
2533 *Euplexia benesimilis* McD.
2535 *Phlogophora iris* Gn.
2540 *Euherrichia monetifera* Gn.
2576 *Leuconycta diphteroides* form *obliterata* Grt.
2577 *Leuconycta lepidula* Grt.
2585 *Amphipyra tragopoginis* Linn.
2586 *Amphipyra glabella* Morr.
2607 *Hyppa xylinoides* Gn.
2647 *Elaphria festivoides* Gn.
2655 *Platyperigea multifera* Wlk.
2662 *Proxenus miranda* Grt.
2682 *Laphygma frugiperda* A. & S.
2715a *Pyrrhia umbra exprimens* Wlk.
2941 *Rhodophora florida* Gn.
3122 *Erastria concinnimacula* Gn.
3252 *Autographa falcifera* Kby.
3254 *Autographa rectangula* Kby.
3260 *Autographa octoscripta* Grt.
3265 *Autographa ampla* Wlk.
3266 *Autographa selecta* Wlk.
3269 *Autographa brassicae* Riley.
3273 *Autographa putnami* Grt.
3281 *Autographa precationis* Gn.
3285 *Autographa bimaculata* Steph.
3286 *Autographa mappa* G. & R.
3287 *Autographa pseudogamma* Grt.
3289 *Autographa oo* Cram.
3295 *Plusia aereoides* Grt.
3297 *Plusia balluca* Geyer
3304 *Palaeoplusia venusta* Wlk.
3344 *Catocala relicta* Wlk.
3616 *Alabama argillacea* Hbn.
3734 *Epizeuxis americalis* Gn.
3770 *Philometra* sp. probably *metonalis* Wlk.

NOTODONTIDAE

3822 *Ichthyura apicalis* Wlk.
3829 *Datana ministra* Dru.
3849 *Notodonta basitriens* Wlk.
3851 *Pheosia rimosa* Pack.
3853 *Lophodonta ferruginea* Pack.
3857 *Nadata gibbosa* A. & S.
3906 *Heterocampa biundata* Wlk.
3907 *Heterocampa guttivitta* Wlk.
3912 *Dicentria lignicolor* Wlk.
3920 *Schizura ipomoeae* form *cinereofrons* Pack.
3920 *Schizura ipomoeae* Dbldy.
3921 *Schizura concinna* A. & S.
3924 *Schizura unicornis* A. & S.
3939 *Gluphisia septentrionalis* Wlk.

THYATIRIDAE

4004 *Habrosyne scripta* Gosse

DREPANIDAE

4020 *Drepana arcuata* Wlk.

GEOMETRIDAE

4244a *Triphosa haesitata* var. *affirmaria* Wlk. (?)
Eupithecia sp.
4416 *Dysstroma* sp. probably forms *citrata* Linn.
4558 *Euphyia unangulata* var. *intermediata* Gn.
4573 *Eulype* sp., *hastata* group
4612 *Deilinea variolaria* Gn.
4614 *Deilinea erythemaria* Gn.
4664 *Philobia ulsterata* Pears.
4725 *Semiothisa neptaria* var. *trifasciata* Pack.
4908 *Anavitrinella pampinaria* Gn. (?)
4968 *Amphidasis cognataria* Gn.
5007 *Xanthotype sospeta* Dru.
5043 *Hyperetis amicaria* H.-S.
5054 *Metanema inatomaria* Gn.
5055 *Metanema determinata* Wlk.
5080 *Pero morrisonarius* Hy. Edw.
5125 *Caripeta divisata* Wlk.
5144 *Ellopia* sp., *endropiaria* group
5152a *Cingilia catenaria* var. *rubiferaria* Swett.

PYRALIDAE

5446 *Evergestis straminalis* Hbn.
5455 *Nomophila noctuella* D. & S.
5462 *Loxostege chortalis* Grt.
5561 *Phlyctaenia terrealis* Tr.
5564 *Phlyctaenia tertialis* Gn.
5724 *Eurrhypara urticata* Linn.
5725 *Scoparia centuriella* D. & S.

TORTRICIDAE

7317 *Sparganothis pettitana* Fern.

BOOK REVIEWS.

PLANT VIRUSES AND VIRUS DISEASES. F. C. Bawden. Second edition, 294 pages, 47 figs. Price $4.75. The Chronica Botanica Co.: Waltham, Mass. Wm. Dawson Subscription Service Ltd., Toronto.

This publication, prepared by one of the leading plant virus investigators, deals primarily with the nature of viruses, rather than the diseases they cause, and in this respect differs from other text books on virus diseases of plants. This second edition is larger, more up-to-date and has included certain omissions that occurred in the first edition. It gives a well rounded conception of the status of our present knowledge about viruses. It is too much to expect that there will be universal agreement with some of the conclusions contained therein, but these conclusions in turn present a challenge to other investigators.

Chapter I is "an introductory survey" and a good one at that. As in the first volume a virus is defined "as an obligatory parasitic pathogen with at least one dimension of less than 200 m.", though the author admits that this definition will most likely be modified by future work. A short history, views on the nature of viruses, and a review of the situation on nomenclature complete the Chapter. Chapters II and III relate to symptoms, Chapter II being confined to external symptoms and the effects of temperature and environment on their expression and the use of local lesions in quantitative work. In this connection the author rightly points out that this method measures the relative infectivities rather than virus content. In Chapter III the internal symptoms are discussed such as X-bodies, intracellular inclusions and other internal changes. Chapter IV gives a concise and clear interpretation on transmission under grafting, mechanical methods, insects and seed. The conclusion that, in the field, tobacco mosaic and potato virus "X" are most probably not transmitted by insects is questionable, even though insect vectors have not yet been demonstrated. Excepting bean, cucurbit and lettuce mosaics and tobacco ring spot, the author states "that though seed from infected plants often contains virus, the plants raised from such seed are healthy and virus free." For some reason the author has omitted any reference of the work carried out at Cheshunt and in Canada to the effect that tomato mosaic, under certain conditions, is transmitted by seed.

Chapter V on relationship between viruses and their insect vectors makes instructive reading for one who has not specialized in this field. The misuse of the term "incubation period" in the first edition in relation to separation of the two types of insect-transmitted viruses, has been rectified in the second. Virus strains, incubation and acquired immunity constitute Chapter VI. The use of the term immunity in this connection will not meet with general approval, as the author realizes, since many consider this phenomenon to be one of protection rather than immunity.

The role of serological reactions on identification of viruses constitutes Chapter VII, and since these reactions are group-specific, they constitute a very rapid means of identification. Chapter VIII discusses detailed methods of purification of tobacco mosaic, Potato "X" and "Y", tomato

bushy stunt and tobacco necrosis viruses, and also the use of the high-speed centrifuge in purification studies. Chapters X and XI describe the properties of purified virus preparations from standpoints of the chemical, physical and optical properties respectively, phases in which the author is particularly interested. These chapters should be of special interest and instruction to those virus workers who are not familiar with these specialized techniques.

In Chapter XI the inactivation of viruses is discussed under inhibitors, denaturation, heat and ageing, inactivation without loss of serological activity, drying and freezing, and hydrogen ion concentration. The size of virus particles is discussed in Chapter XII, under filterability, sedimentation velocities, viscosity and diffusion. There is also a section on X-rays and electron microscopy which was not included in the first edition. The effect of viruses on metabolism of host and the movement of viruses in the host is discussed in Chapter XIII. Movement is stated as being of two kinds, a slow movement in parenchymetous tissue via plasmodesmata and a rapid movement via the phloem.

The naming and grouping of viruses, their identification and bases of classification constitutes Chapter XIV. The author favours a classification based on the viruses themselves rather than on host relations. He suggests that plant protection and serological tests might be used as a basis in grouping of viruses to which some form of nomenclature could be fitted. However, the application of the serological technique is limited to certain types of viruses, and thus its use in respect to classification is in turn limited. Control of virus diseases in Chapter XV gives a good summary of control practices. The final Chapter discusses the origin and multiplication of viruses and raises the question as to whether viruses are living or non-living entities. It is pointed out that until the word life has been given an accurate definition, there is little chance of answering the above question, since the conclusion of various workers depends on their own viewpoint. This is a very intriguing Chapter with which to end a well written, instructive and most useful book on plant viruses.

G. H. BERKELEY.

FUNDAMENTALS OF SOIL SCIENCE. By C. E. Miller and L. M. Turk. Published by John Wiley & Sons, Inc., New York. $3.75.

This book was written for use as a college textbook, as a reference book for farmers and owners of farm lands and as an aid to anyone desiring information on soils and their culture. The book covers a wide field, a fact indicated by the following brief summary of the principal topics discussed: classification and development of soils, physical and chemical properties, soil moisture, organic matter, nutrient requirements for different crops, farm management practices, and the selection of soils for various crops.

This book is well prepared and clearly written. General principles of soil science are emphasized and explained in simple terms, omitting, so far

as possible technical discussions, particularly of debatable points. For this reason it is more suitable as a textbook for elementary rather than advanced courses in soils.

From a Canadian viewpoint the weakness of the book lies in the fact that where environmental factors affect the discussions the examples used refer to conditions in the United States. However, this weakness applies also to nearly all books on soils. Insofar as general principles are concerned Canadians will find this book a valuable and modern source of information. As might be expected from the reputation of the authors this is one of the better textbooks on the general principles of soil science.

A. LEAHEY.

CONSTITUENTS OF WHEAT AND WHEAT PRODUCTS. By C. H. Bailey. The Reinhold Publishing Corporation, 330 West Forty-Second Street, New York, U.S.A., 1944. 332 Pages, Price $6.50.

This is a monograph written by Dr. C. H. Bailey, Professor of Agricultural Biochemistry and Director of the Agricultural Experiment Station, the University of Minnesota, for the American Chemical Society Monograph Series. As the title indicates, it deals mainly with the descriptive biochemistry of wheat and wheat products, and continuously cites literature, both historic and up-to-date, on researches in wheat and wheat products. To the layman the presentation might be found laborious, but to the research worker and to persons wanting a ready reference to this subject, the book is invaluable.

The book is divided into 16 chapters, 7 of which are devoted to the proteins. The remainder give an account of researches on the starch, sugars, gums, pentosans, hemicelluloses, cellulose, lipids, phospholipids, sterols, minerals, the halogens, sulphur, selenium, acidity, wheat and flour pigments, and vitamins of wheat and wheat products. It is not a handbook of analytical methods, although it does refer in many cases to the methods employed, in order to present the data more clearly. Many comparative tables are given which should be very useful to those interested in obtaining ready information on any of the constituents found in wheat and its products. The book quickly dispels any ideas of simplicity of the constituents of wheat, both as to the amounts and properties, but it gives an appreciation of the vast amount of research which has been done on the subject, and brings that knowledge right up to the time of publication.

A. G. O. WHITESIDE

TERMITES (ISOPTERA) FROM THE AUSTRALIAN REGION. By Gerald F. Hill. 479 pp., 24 plates, 353 figs. Commonwealth of Australia, Council for Scientific and Industrial Research, Melbourne, 1942.

This work is a treatment, primarily systematic, of the termites occurring in Australia, New Guinea, and in the islands south of the equator

between 140° E. and 170° W. The author recognizes 193 species and 8 subspecies in the region and arranges them in 14 genera and 4 families; 32 of the species and 1 subgenus are described as new. The treatment is comprehensive; all of the known castes are described, often at some length, and a key to genera based on soldiers and keys to subgenera are included. The citations to the literature include references concerned with biology and economic importance, as well as those dealing with morphology and systematics, and what little is known of the biology of the various species is summarized in the text. Most of the figures are of cephalic and thoracic structures offered as an aid in identification. On the plates are reproduced 41 excellent photographs of the nests and work of termites. Of special interest to the general student are the photographs and the description of the nests of *Hamitermes meridionalis* (Frogg.). These nests may measure 12 by 10 by 3½ feet and are always oriented so that the long axes are directed north and south. The volume includes a glossary and is well indexed.

The volume is a product of many years of study on the part of the author, who has arranged his material to show what is not known, as well as what is known, of the very interesting termite fauna of his region. Although the book is printed by a lithographic process, the format is pleasing and the figures are well reproduced.

W. J. Brown

BULLETINS FROM THE ONTARIO HORTICULTURAL STATION

Vineland Station, Ontario

The Ontario Department of Agriculture is to be congratulated on the quality of a number of bulletins recently issued from the Horticultural Station at Vineland, Ontario. These are farmers' bulletins published in a very attractive form, exceedingly well illustrated and well written. They should attract the attention of the fruit grower and retain his interest.

Orchard Soil Management. By E. F. Palmer and J. R. Van Haarlem. Bulletin 437—January, 1944.

This bulletin runs to 45 pages and contains a large number of illustrations, the cover illustration being in colour. Sources of organic matter, clean cultivation and cover crops, sod culture, and intermediate systems of soil management are discussed. References are given to other publications where further information may be secured. This bulletin itself, however, discusses the problem of orchard soil management in a manner which should be intelligible to the average fruit grower.

The Grape in Ontario. By C. B. Kelly. Bulletin 438—February, 1944.

The selection of varieties, planting, care of the young vineyard, trellising, pruning, training and tying, and vineyard soil management are discussed. There is also a good section on insects and diseases.

ORCHARD GRAFTING. By W. H. Upshall. Bulletin 439—April, 1944.

This bulletin gives a thorough discussion in simple language of the methods of grafting, and should prove exceptionally useful because of the excellent illustrations. Many of them are line drawings by Miss L. Heringa of the Department of Horticulture, O.A.C., Guelph. These drawings show the manner in which grafting should be done. The cover photograph is a very excellent illustration in colour of bridge grafting.

CURRANTS AND GOOSEBERRIES. By W. J. Strong. Bulletin 440—April, 1944.

This bulletin discusses pollination, varieties, propagation, soil and location, and the establishment and care of the plantation. More important diseases are discussed by Professor J. E. Howitt, Department of Botany, O.A.C., and chief insect pests by R. W. Thompson, Provincial Entomologist.

SCIENTIFIC AGRICULTURE

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SOIL-PLANT RELATIONSHIPS AND VERTICAL ZONATION IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA[1]

R. H. SPILSBURY[2] AND E. W. TISDALE[3]

Experimental Farms Service

[Received for publication January 17, 1944]

The broad conception of climate is that progressive series of changes in moisture and temperature conditions occur at different latitudes. These differences produce wide climatic zones with which are associated the main soil and plant formations.

In the southern interior of British Columbia this condition is modified materially by the mountainous nature of the country. A wide variety of climates is produced in comparatively small areas due to the effect of mountain passes, peaks and valleys upon prevailing winds, and of elevation and exposure on temperature and moisture conditions. The net result is that the distribution and extent of soil and vegetation zones is more dependent upon topography than upon latitude.

Because of the roughness of topography and in some cases unfavorable climate, the bulk of the interior region is suited for forestry and grazing rather than for cultivated agriculture. The purpose of the present study was to obtain a better understanding of zonal soil-plant relationships in the area, with particular regard to the application of such information to range utilization. The data presented herein were obtained mainly by means of a soil-plant survey conducted on a section of country known as the Tranquille Range.

The Tranquille Range is situated near the town of Kamloops, (see Figure 1) in the southern interior of British Columbia. Climate and topography are typical for this section of the Province. The lowest elevation is 1,100 feet above sea level, in the bottom of the Thompson River valley. From this point there is a fairly steady increase in altitude to the height of land at 6,100 feet. The general exposure is southerly, although isolated knolls, rocky escarpments, and deep ravines provide an interesting variety of exposures.

The soil covering the entire area is a stony, sandy loam glacial till. There are no significant differences in texture, and the soil "skeleton" is remarkably uniform. The morphological changes in the profile and the vegetation changes are consequently ascribed to climatic differences.

[1] Contribution from the Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Soil Specialist, Forest Branch, Department of Lands, Victoria, B.C., formerly Experimental Farms Service representative on the British Columbia Soil Survey Staff.

[3] Agrostologist, Dominion Experimental Station, Swift Current, Sask., formerly Officer-in-Charge, Dominion Range Experimental Sub-Station, Kamloops, B.C.

FIGURE 1. *(see opposite page)*. Map of part of the Tranquille Range, British Columbia.

Ascending from the lowest elevation there are six distinctive profiles which correspond to the Brown Earth, Dark Brown Earth, Black Earth and three Podsol sub-zones. Associated with each soil type is a corresponding plant community and these are described as Lower, Middle and Upper Grasslands, Montane, Subalpine and Upper Subalpine Forests. The transition from arid grassland to subalpine forest occurs within a horizontal distance of about 30 miles and a vertical distance of 5,000 feet.

The discussion deals in some detail with the succession of changes in soils and vegetation under a vertical distribution of zones, and to a lesser extent with soil-plant relationships within each zone.

REVIEW OF LITERATURE

The relationship between zonal soil and vegetation types is mentioned in most treatises on plant ecology or pedology. There are few references, however, dealing with this subject in any but general terms. Weaver (23), de Sigmond (17), and Thornthwaite (19) deal with vegetation, soil and climate respectively, and discuss interrelationships from their own points of view.

A distinction between vertical and horizontal zonation of soils was recognized in 1899. Dokutschajeff, as quoted by Glinka (9), described vertical soil zones of the Caucasus mountains. Joffe (11), summarizes much of the more recent European literature on soils and vegetation of mountainous regions.

In North America, studies of soil and plant zonation have been confined chiefly to the broad horizontal zones of the central part of the continent. In the mountainous regions of the West, the effects of altitude and exposure on the distribution of plant species and communities have been noted by numerous investigators. In few cases, however, has any attempt been made to determine the nature of the soil types occurring under these same conditions, or the relationship existing between soil and vegetation types.

The only reference the authors have found dealing with a similar study is by Thorp (20). He described a series of six soil zones at various elevations in the Big Horn Mountains of Wyoming and observed a distinctive plant community associated with each. These included desert vegetation, four types of grassland, and one of coniferous forest. The description of plant types is much less complete than that of the soil profiles. Daubenmire (5) has described three grassland zones, in southeastern Washington, and found these associated with three distinct soil series. The same

Legend for Figure 1 (*see opposite page*).

Contour interval	500 feet.	Savanna (Ponderosa pine)	IV
Roads and trails	- - - - - - -		
Zonal boundaries	....	Lower Podsol Montane Forest	V
Brown Earth Lower Grassland	I	Middle Podsol Subalpine Forest	VI
Dark Brown Earth Middle Grassland	II	Upper Podsol Upper Subalpine Forest	VII
Black Earth Upper Grassland	III		

author (6) has recently reviewed vegetational zonation in the Rocky Mountain region, but soil relationships are given only brief mention. Pearson (13) has investigated the relation of forest types to climate and soil in the southwestern United States.[4]

CLIMATIC DATA

The southern interior of British Columbia, lying between the Coast Range to the west and the Selkirk Mountains to the east, is described generally as a region of low precipitation and high summer temperatures. Since the official weather stations are located mainly in the valley bottoms, their records are of limited value in revealing the variations of climate at different altitudes.

The data used in the following discussion were obtained mainly on the Tranquille Range area from instruments established at typical sites in the various soil-plant zones during the period 1938 to 1940 inclusive. Records of precipitation and temperature extending over a much longer period were available from the Tranquille Sanitorium which is located at the lower edge of the study area, in the Lower Grassland-Brown Earth Zone.

Evaporation was measured by means of spherical Livingston atmometers set at 12 inches above ground level. Records of soil temperature near the surface were obtained by the use of thermographs. Measurements at a depth of 12 inches were made with mercury thermometers suspended in iron pipes driven into the ground as described by Bates and Zon (1).

Precipitation and Evaporation

The 3-year averages of monthly precipitation during the growing season at the various stations are presented in Table 1. The monthly distribution

TABLE 1.—AVERAGE MONTHLY PRECIPITATION AT DIFFERENT ALTITUDES, TRANQUILLE RANGE, 1938 TO 1940 INCLUSIVE

Soil Plant Zone	Altitude	Precipitation						
		April	May	June	July	Aug.	Sept.	Total
	ft.	in.	in.	in.	in.	in.	in.	in.
Brown Earth Lower Grassland	1400	0 32	0.67	1.44	0.57	0.66	0.59	4.25
Dark Brown Earth Middle Grassland	2300	0.41	0.97	1.70	0.78	0.97	0.72	5.55
Black Earth Upper Grassland	2850	0.45	1.30	1.96	1.08	1.04	0.83	6.66
Lower Podsol Montane Forest	3300	0.61	1.44	2.12	1.23	1.18	1.12	7.70

of rainfall in each zone corresponded to that of the southern interior of British Columbia generally, with minimum and maximum amounts falling

[4] Since completion of this manuscript, a paper by Martin and Fletcher (26) dealing with vertical zonation in southern Arizona has come to hand. Their study deals mainly with soils and presents detailed data on the physical, chemical and micro-biological characteristics of several zonal groups. The results of this Arizona study are in general agreement with those obtained in the soil-plant survey of the Tranquille Range.

in April and June respectively. Between zones there was a steady increase in precipitation with increasing altitude.

Records from comparable stations indicate that these data are reasonably representative of long-term trends. The 31-year average April to September rainfall at Tranquille is 4.15 inches, while at Knouff Lake, in the Montane forest zone (altitude 3750 feet) it is 7.05 inches.

Evaporation was recorded for portions of two seasons only but the differences obtained between zones seemed great enough to warrant presentation of the data. In Table 2, the average weekly evaporation in each zone during May and June is presented along with the average precipitation for the same period.

TABLE 2.—EVAPORATION, PRECIPITATION AND THE P/E RATIO AT DIFFERENT ALTITUDES ON THE TRANQUILLE RANGE, MAY AND JUNE, 1939–1940

Soil plant zone	Altitude	Weekly average		
		Evaporation	Precipitation	P/E ratio
	ft.	cc.	in.	
Brown Earth Lower Grassland	1400	405	0.26	6.4
Dark Brown Earth Middle Grassland	2300	330	0.33	10.0
Black Earth Upper Grassland	2850	205	0.41	20.0
Lower Podsol Montane Forest	3300	150	0.43	28.7

The P/E ratio was calculated according to the method used by Livingston and Shreve (12). Precipitation in inches was divided by evaporation in cubic centimetres and the product multiplied by 10,000 to give a figure of reasonable size. It will be noted that differences in evaporation between the various zones were greater relatively than the differences in precipitation. This is emphasized by the P/E ratio which shows considerable variation in moisture conditions with changes of only a few hundred feet in elevation.

Air and Soil Temperatures

Data on air temperature were obtained during two seasons in two zones. The data are summarized in Table 3. The mean difference for the 4 months was 9.3° F., or almost 5 degrees per thousand feet of altitude.

TABLE 3.—MEAN MONTHLY MAXIMUM AND MINIMUM AIR TEMPERATURES, TRANQUILLE RANGE. AVERAGE FOR 1938 AND 1939

Soil plant zone	June		July		Aug.		Sept.		Average		Mean
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Brown Earth Lower Grassland	52	72	58	83	47	84	53	72	52.5	77.7	65.1
Lower Podsol Montane Forest	41	62	45	74	43	78	38	65	41.8	69.8	55.8

Daily and hourly fluctuations in soil temperature were found to be slight at a depth of 12 inches, hence individual weekly readings were considered to be reliable for purposes of zonal comparison. Data obtained in four soil-plant zones are summarized in Table 4.

TABLE 4.—SOIL TEMPERATURES AT 12-INCH DEPTH IN VARIOUS ZONES OF THE TRANQUILLE RANGE, MAY TO SEPTEMBER, 1940

Soil plant zone	Altitude	Soil temperatures		
		High max.	Low min.	Seasonal mean
	ft.	°F.	°F.	°F.
Brown Earth Zone Lower Grassland	1400	76	48	66
Dark Brown Earth Middle Grassland	2300	73	45	62
Black Earth Upper Grassland	2850	66	40	55.5
Lower Podsol Montane Forest	3300	58	38	51

The differences between the sites, while not great, were consistent throughout the period of study.

Soil temperatures close to the surface varied more widely than those at a 12-inch depth. The data obtained in two grassland zones are summarized in Table 5.

TABLE 5.—SOIL TEMPERATURES AT 3-INCH DEPTH IN TWO ZONES OF THE TRANQUILLE RANGE, MAY TO JUNE, 1940

Soil plant zone	Altitude	Soil temperaturcs		
		Mean max.	Mean min.	Mean
		°F.	°F.	°F.
Brown Earth Lower Grassland	1400	76.5	59.5	68.0
Dark Brown Earth Middle Grassland	2300	63.5	44.5	54.0

The data from this and the preceding table indicate that soil temperatures decreased fairly regularly with increased altitude, the greatest differences occurring in the surface soils of the different zones.

The influence of altitude on temperature, and thus on development of vegetation and soils, is reflected in the data for length of the frost-free period. During the years 1938 and 1939 for which data are available, the average frost-free period was 178 days in the Lower Grassland zone and 116 days in the Montane forest zone. Comparable information was not obtained for the other zones.

Discussion of Climatic Data

The data indicate that, in the zones for which records were obtained, precipitation increased while evaporation, mean temperatures, and the length of the frost-free period decreased with increasing altitude. These results are in general accord with those obtained by numerous investigators in the Rocky Mountain region and elsewhere.

Although climatic data were not obtained for the zones above the Montane, observations of length of growing season, depth of snow cover, and soil moisture conditions indicated that the trends found at lower altitudes tended to persist at higher levels. That such is the case with temperature and length of frost-free season seems likely from the results obtained by other workers in comparable regions. Price and Evans (14) found that in the Wasatch Mountains of Utah, mean air and soil temperatures and the length of the frost-free season decreased steadily from the lowest to highest (spruce-fir) zone studied. Daubenmire (6) states that mean air temperatures decrease on the average about 3 degrees Fahrenheit per thousand feet in the Rocky Mountain region.

On the other hand it has been found that moisture conditions often do not become progressively more favorable up to the highest altitudes. Daubenmire (6) reviewing climatic conditions affecting Rocky Mountain vegetation, points out that maximum precipitation frequently occurs well below the tops of mountain ranges. Precipitation usually reaches a maximum in either the spruce-fir (Subalpine), or Douglas fir (Montane) zone. Similarly, the decrease in evaporation with increasing altitude tends to be checked near the upper timber line due to the influence of decreased atmospheric pressure and increased insolation and wind velocity. Most studies in the Rocky Mountain region (6, 13, 25) have shown evaporation to be at a minimum in either the spruce-fir or Douglas fir zones and to increase in the zones above and below.

Taking both local observations and the results of studies in comparable areas into account, it appears probable that the P/E ratio in the Tranquille area increases to a maximum in the Subalpine (spruce-fir) zone and decreases in the Upper Subalpine type above.

METHODS OF STUDY

Preliminary inspection of larger units was followed by more intensive study of a considerable number of sample areas. Each site represented either conditions typical of large areas, or interesting variations of these conditions; 160 of these sample plots were established on the Tranquille range.

At each site, the location was determined and mapped, and the topographical features noted and described. A soil pit was dug, the profile studied and described, and samples obtained for subsequent determinations of pH, texture, etc.

The plant cover at each site was described, and the constituent species rated for abundance, height, vigour, etc. For plant studies, the area occupied by each site was taken as 100 square metres, (4 square rods). This unit was found to be one which could be studied conveniently by the methods used, and was large enough to give a representative list of species.

Estimates of the various characters of the plant cover were made according to numerical scales. The scale used for abundance was as follows:

5 — Dominant, very abundant.
4 — Sub-dominant, abundant.
3 — Common.
2 — Occurring, but not common.
1 — Rare.

A collection was made of virtually all plant species encountered in the study. The identifications of grasses were checked by Dr. J. R. Swallen, United States Dept. of Agriculture, Washington, D.C., while Dr. H. A. Senn, Division of Botany, Science Service, Ottawa, checked those of other flowering plants. Miss Frances Wynne, Botany Dept., University of Michigan, determined the mosses, and Mrs. Lucy C. Raup, Jamaica Plain, Massachusetts, identified the lichens.

Following the method of Braun-Blanquet (2), a table was prepared for each zone in which were listed the species found at each site, together with their abundance, life-forms, etc. From this table was derived the *average abundance* and *frequency* (percentage occurrence) of each species. By comparison of the summaries for the different zones, the *characteristic species* for each were determined. The latter were forms confined largely or entirely to one zone.

As the work progressed, zonal boundaries were recognized and mapped. In most cases it was found that the boundaries of the major soil and plant types corresponded closely. Additional study was given to areas in which discrepancies occurred.

Near the close of the survey, one typical site in each zone was revisited, and samples from the various soil horizons obtained for chemical study.

In addition to the survey of the Tranquille area, short excursions were made to representative areas in adjacent parts of the Interior. A few sites were studied at each of these localities, in order to test the results obtained at Tranquille.

The soil-plant survey was made during the season of 1938. In the following two years, further plant studies were made at a number of sites in the grassland zones. Areas possessing well developed soil profiles and vegetation approximating the climax type were chosen for this work. At each site several meter quadrats were established and their cover measured by the area-list method. These plots were clipped later to determine the yield of forage.

VEGETATION OF THE GRASSLAND ZONES

Three grassland communities occur in association with the three zonal types of grassland soils. On account of their vertical distribution, these plant associations are designated in this study as the Lower, Middle, and Upper Grassland zones.

The Lower Grassland belt occurs at elevations of 1100 to about 2300 feet and coincides with the Brown Earth zone. From 2300 to 2800 feet is found the Middle Grassland zone, associated with Dark Brown soils. The Upper Grassland type extends from the upper edge of the Middle

FIGURE 2. General view of Tranquille Range, looking north from south side of Thompson River Valley. Snow still present on Upper Grassland and Forest Zones in March.

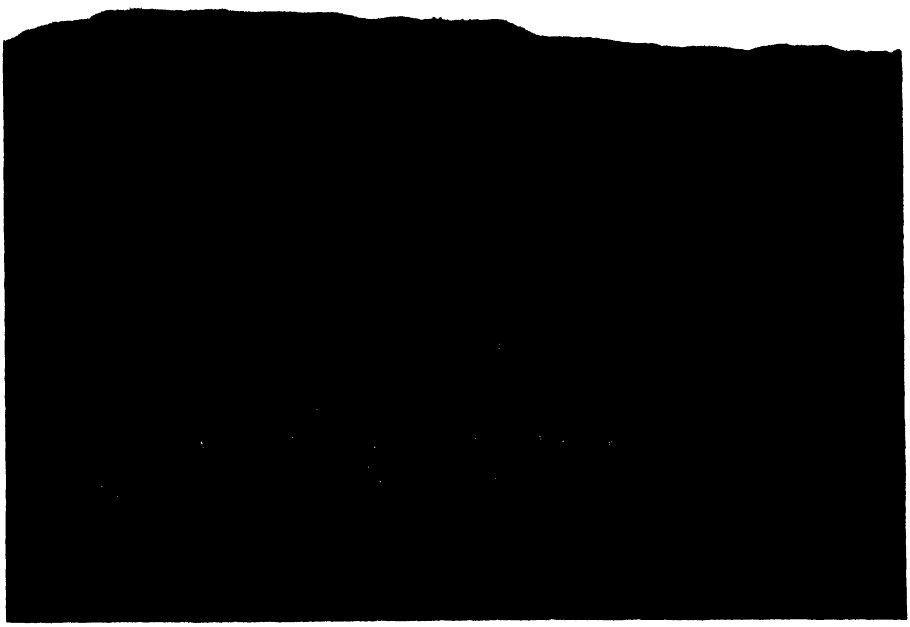

FIGURE 3. Upper Grassland zone with Montane forest on higher land in the background. Note clumps of aspen in depressions and intrusion of Douglas fir into grassland on sheltered slopes.

Grasslands to the forest edge at about 3200 feet and coincides with the Black Earth zone.

All three grassland associations are dominated mainly by perennial bunchgrasses, particularly *Agropyron spicatum* (blue-bunch wheatgrass). The whole grass land formation belongs to the Palouse Prairie as described by Weaver (24), Weaver and Clements (23) and others. This is an extensive type characteristic of the Intermountain regions of northern Utah, southern Idaho, eastern Washington and Oregon and southern British Columbia. Daubenmire (5) has reported the presence of three main associations in the Palouse prairies of southeastern Washington and adjacent Idaho. These associations, described as the *Artemisia-Agropryon*, *Agropyron-Poa*, and *Festuca-Agropyron* zones, correspond to a considerable degree with the three grassland types recognized on the Tranquille range.

Botanical Composition

A list of the species occurring commonly on the Tranquille grasslands, together with their relative frequency and abundance is presented in Table 6. These data, based on a study of some 75 sample plots distributed

TABLE 6.—LIST OF SPECIES OCCURRING COMMONLY ON GRASSLAND ZONES OF THE TRANQUILLE RANGE

Scientific name	Popular name	Frequency		
		Lower	Middle	Upper
		%	%	%
Shrubs				
Artemisia tridentata Nutt.	Sagebush............	**90**	20	—
Chrysothamnus nauseosus (Pall) Britt.	Rabbit brush	63	45	—
Rosa sp.	Wild rose	—	5	40
Symphoricarpos racemosus Mich.	Snowberry	—	—	20
Grasses and Sedges				
Agropyron spicatum Pursh. var. *inerme* Heller	Bluebunch wheatgrass	**75**	**72**	**63**
Bromus tectorum L.	Downy bromegrass	25	**52**	10
Festuca scabrella Torr.	Rough fescue	—	10	**25**
Koeleria cristata (L) Pers.	Junegrass	16	48	63
Poa pratensis L.	Kentucky bluegrass	—	5	**50**
Poa secunda Presl.	Dwarf bluegrass	**90**	**80**	40
Sporobolus cryptandrus (Torr) A. Gray	Sand dropseed	**63**	15	—
Stipa comata Trin. & Rupr.	Common speargrass	**63**	**55**	15
Stipa columbiana Macoun	Columbia speargrass	—	—	**67**
Carex praegracilis W. Boott	Graceful sedge	—	6	50
Juncus balticus Willd.	Dwarf rush	—	5	40
Forbs*				
Achillea millefolium L.	Yarrow	4	47	**75**
Antennaria dimorpha T. & G.	Dwarf everlasting	**90**	**95**	**60**
Antennaria parvifolia Nutt.	Everlasting	—	25	**63**
Artemisia frigida Willd.	Pasture sage	50	35	**5**
Astragalus serotinus A. Gray	Poison vetch	—	—	**63**
Balsamorhiza sagittata Nutt.	Balsam root	24	**53**	**25**
Delphinium bicolor Nutt.	Dwarf larkspur	—	14	**65**

* Forbs are non-grasslike, herbaceous plants.

TABLE 6.—LIST OF SPECIES OCCURRING COMMONLY ON GRASSLAND ZONES OF THE TRANQUILLE RANGE—*Concluded*

Scientific name	Popular name	Frequency		
		Lower	Middle	Upper
		%	%	%
Forbs—*Concluded*				
Erigeron compositus Pursh.	Fleabane	—	18	32
Erigeron filifolius (Hook) Nutt.	Fleabane	40	3	—
Erigeron corymbosus Nutt.	Fleabane	5	55	50
Geranium viscosissimum F. & M.	Geranium	—	—	30
Lomatium macrocarpum (Nutt.) C. & R.	Parsley	48	48	10
Lithospermum pilosum Nutt.	Puccoun	—	10	36
Opuntia fragilis Haw.	Cactus	60	20	—
Taraxacum officinale. Weber	Common dandelion	—	5	32
Taraxacum erythrospermum Anderz	Red-fruited dandelion	20	40	40
Zygadenus venenosus Wats.	Death camas	—	5	50

N.B. Frequency figure in bold type indicates dominance of the species in that zone.

over the three zones, indicate the extent to which all three associations are dominated by grasses and composites. Certain genera, such as *Agropyron*, *Stipa*, *Antennaria* and *Artemisia* are particularly well represented, although within each genus the same species do not usually occur in all three zones. For example, *Stipa* is represented by *S. comata* in the Lower and Middle grasslands, and by *S. columbiana* in the Upper zone. The outstanding exception in this regard is *Agropyron spicatum* which occurs abundantly in all three types.

The number of species increases from the lower to the higher zones. Only 15 species were found occurring with a frequency of 10% or more in the Lower Grasslands, as compared to 20 species in the Middle zone and 25 in the Upper Grassland association.

The Lower Grassland zone is dominated by 4 grasses *Agropyron spicatum*, *Poa secunda*, *Stipa comata* and *Sporobolus cryptandrus*, along with 1 shrub, *Artemisia tridentata* and 1 dwarf forb, *Antennaria dimorpha*. These 6 species comprise about 90% of the sparse plant cover. Common plants include 1 shrub, *Chrysothamnus nauseosus*, 1 cactus, *Opuntia fragilis*, and a few herbaceous species, *Artemisia frigida*, *Erigeron filifolius* and *Lomatium macrocarpum*.

The dominants of the Middle Grassland zone include the same species of *Agropyron*, *Poa*, *Stipa*, and *Antennaria* as were listed for the Lower Grasslands. In addition, *Bromus tectorum* is dominant on certain overgrazed areas. Common species include *Chrysothamnus nauseosus*, *Koeleria cristata*, *Balsamorhiza sagittata*, *Achillea millefolium* and *Erigeron corymbosis* *Artemisia tridentata* is common only on the lower fringes of the zone.

The Upper Grassland association does not exhibit such clear cut dominance of a few species as is found in the lower zones. The principal species are 4 grasses, namely *Agropyron spicatum*, *Festuca scabrella*, *Poa pratensis* and *Stipa columbiana*. In addition, there are several species

which, while not ranking as dominants, are quite abundant. This group comprises a grass *Koeleria cristata*, a sedge *Carex praegracilis*, a dwarf rush *Juncus balticus* and a number of forbs including *Antennaria parvifolia*, *Achillea millefolium*, *Astragalus serotinus*, *Delphinium bicolor*, *Erigeron corymbosus* and *Zygadenus venenosus*.

A conspicuous feature of the zone is the presence of clumps of aspen (*Populus tremuloides*) in shallow depressions and on sheltered slopes. Two shrubs, *Rosa* sp. and *Symphoricarpos racemosa* occur in patches on favored locations.

The three zones differ greatly in the nature of their characteristic plants. Those of the Lower Grasslands are drought-tolerant species of southern origin such as *Artemisia tridentata*, *Erigeron filifolius*, *Opuntia ragilis* and *Sporobolus cryptandrus*. The characteristic species of the Upper Grassland are relatively mesic forms such as *Poa pratensis*, *Stipa columbiana*, *Carex praegracilis*, *Delphinium bicolor*, and *Geranium viscosissimum*.

The Middle Grassland zone contains practically no characteristic species. Absence of the characteristic plants of the other two associations is its main distinguishing feature floristically.

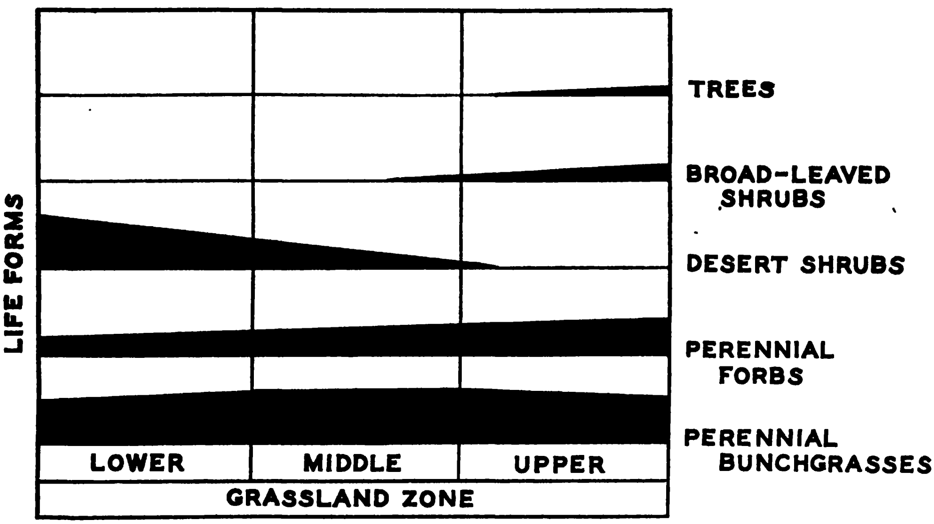

FIGURE 4. Relative Importance of Main Life-forms in grassland zones. Tranquille Range.

Life Forms and Seasonal Growth

The life forms of plants, representing the reaction of the plant body to the environment, constitute valuable indicators of habitat. The nature and relative importance of the principal life forms occurring in the Tranquille grasslands are indicated in Figure 4. Both numbers of species and abundance of individual plants in each class were considered in preparing this figure.

The principal life form is the perennial bunchgrass, well adapted for existence in all three zones, but reaching its maximum abundance in the Middle Grassland type. Rhizomatic grasses are common only in the moister

portions of the Upper Grasslands. The xeric desert shrubs are restricted to the two lower zones and attain most importance in the Lower Grassland association. Broad-leaved shrubs (*Rosa*, etc.) are confined to the moister parts of the Upper Grasslands.

Perennial forbs, while occurring in all three zones, are much more abundant and luxuriant in the Upper Grassland association. Most of the forbs which do occur in the lower zones are either dwarf forms (*Antennaria dimorpha*) or short-season, drought-escaping species (*Balsamorhiza sagittata, Lomatium macrocarpum*). Moisture conditions are generally unsuitable for tree growth except in favoured locations in the Upper Grassland zone.

Studies of seasonal growth development over a period of five years revealed marked differences in the three zones. The average date of first growth was March 18 in the Lower, March 27 in the Middle, and April 9 in the Upper Grassland zone. These differences reflect the influence of decreasing soil and air temperatures with increasing altitude. In the Lower Grasslands, the vegetation usually cured and became dormant during July and August, reviving to some extent with the autumn rains. A similar course occurred in the Middle Grassland, with the date of curing averaging a few days later. In the Upper Grassland zone, moisture conditions were sufficiently favorable to maintain much of the vegetation in a green state throughout the summer in average years.

Structure and Productivity

The plant cover of the grasslands becomes progressively denser and more productive with increasing altitude. A summary of data on basal cover and yield from 45 meter quadrats established on representative areas of relatively climax vegetation in the three zones is presented in Table 7.

TABLE 7.—DENSITY AND YIELD OF CLIMAX VEGETATION IN THE GRASSLAND ZONE, 1939

Zone	Density	Yield
	%	lb. per acre
Lower Grassland	7	370
Middle Grassland	11	560
Upper Grassland	16	1200

It will be noted that the increase in yield from the lowest to highest zone is greater than that in density, indicating that taller growth is a factor affecting productivity.

Because of the relatively open nature of the plant cover, stratification is generally poorly developed in the two lower zones. In the Upper Grassland there are two fairly well marked strata, an upper layer of grasses and taller forbs and a lower layer of shorter forbs.

Successional Relationships

It was evident during the course of the soil-plant survey that the plant cover of the Tranquille grasslands had been disturbed greatly by overgrazing. Subsequent study of lightly grazed sites yielded considerable information regarding the nature of the climax vegetation in each zone.

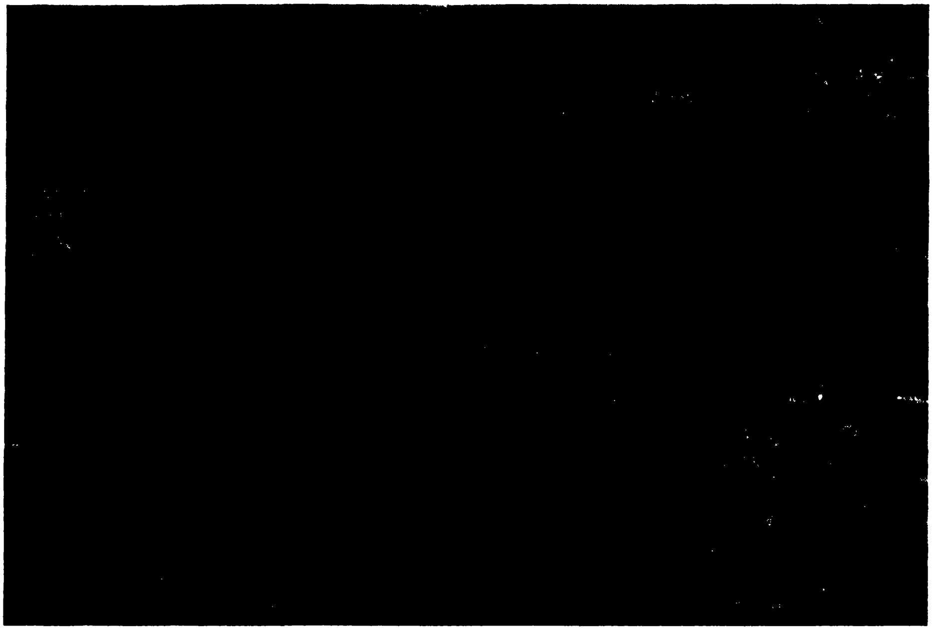

FIGURE 5. Typical open cover of bluebunch wheatgrass on meter quadrat located in climax vegetation of the Lower Grassland zone.

FIGURE 6. Heavy sod, composed mainly of Kentucky bluegrass, in meter quadrat on deep soil in Upper Grassland zone.

In the Lower Grasslands, the climax vegetation appears to consist mainly of perennial bunchgrasses, particularly *Agropyron spicatum* which forms practically pure stands on many undisturbed sites. In the Middle Grassland type, these same bunchgrasses are clearly dominant.

In the Upper Grassland area, undisturbed sites were very few and it was more difficult to ascertain the nature of the original plant cover. Apparently bunchgrasses, especially *Agropyron spicatum* and *Festuca scabrella* are the principal climax species, but certain other grasses and many forbs apparently occurred in considerable abundance in the original vegetation.

VEGETATION OF THE FOREST ZONES

Three forest communities are associated with the three types of podsols. These associations are designated as the Montane, Subalpine and Upper Subalpine forests and coincide with the Lower, Middle and Upper Podsols respectively. The Montane forest occurs immediately above the Upper Grassland zone, at altitudes of 3200 to 4000 feet and has Douglas fir (*Pseudotsuga taxifolia*) as its main climax dominant. Above this zone, from 4000 to 5800 feet occurs a forest type whose climax dominants are Engelmann spruce (*Picea Engelmanni*) and subalpine fir (*Abies lasiocarpa*). From 5800 to the height of land at 6100 feet is the Upper Subalpine type, characterized by many of the same dominants as those of the Subalpine, but distinguished by differences in tree density and growth as well as by the presence of extensive treeless openings.

The Montane forest belongs to one of the major Rocky Mountain plant formations, the Petran Montane type of Weaver and Clements (22) or the Douglas Fir zone of other authors (6). Similarly the Subalpine type corresponds to the Petran Subalpine formation (22) or Spruce-Fir zone (6). The Upper Subalpine type of this study probably represents a transition between the Subalpine and Alpine zones. The occurrence of somewhat similar vegetation along the upper edge of the Subalpine forest has been reported by several investigators (6, 7) in the Rocky Mountain region. The altitude of the Tranquille area is not sufficient to allow the development of the Alpine zone which does not occur below 7000 feet in this vicinity.

Botanical Composition

A list of the species occurring commonly, along with their relative frequencies in the different forest zones is presented in Table 8. Floristic-

TABLE 8.—LIST OF SPECIES OCCURRING COMMONLY ON FOREST SITES, TRANQUILLE RANGE

Scientific name	Popular name	Frequency		
		Montane.	Sub-Alp.	Upper Sub-Alp.
Trees		%	%	%
Abies lasiocarpa (Hook) Nutt.	Subalpine fir	—	60	40
Picea Engelmanni Parry.	Engelmann spruce	5	70	80
Pinus ponderosa Dougl.	Ponderosa pine	20	—	—
Pinus contorta Dougl. var. *latifolia* Engelm.	Lodgepole pine	80	90	5
Pseudotsuga taxifolia (Lamb) Brit.	Douglas fir	65	10	—
Populus tremuloides Michx.	Aspen, poplar	85	20	—
Salix spp.	Willow	65	40	50

TABLE 8.—LIST OF SPECIES OCCURRING COMMONLY ON FOREST SITES, TRANQUILLE RANGE —*Concluded*

Scientific name	Popular name	Frequency		
		Montane	Sub-Alp.	Upper Sub-Alp.
		%	%	%
Shrubs				
Amelanchier alnifolia Nutt.	Saskatoon	35	—	—
Lonicera involucrata Banks	Twinberry	5	40	5
Pachystima myrsinites Raf.	False box	10	**60**	—
Rosa spp.	Rose	**90**	20	—
Sheperdia canadensis (L) Nutt.	Sopolallie	**90**	30	—
Spiraea lucida Dougl.	Spiraea	60	10	—
Vaccinium membranaceum Dougl.	Huckleberry	15	**80**	10
Grasses and Sedges				
Calamagrostis rubescens Buckl.	Pinegrass	**100**	30	—
Danthonia intermedia Vasey	Oatgrass	—	—	**40**
Deschampsia atropurpurea (Wahl) Scheele	Mountain hairgrass	—	5	**65**
Phleum alpinum L.	Alpine timothy	—	—	35
Trisetum spicatum (L) Richter	False oatgrass	—	20	50
Carex concinnoides Mack.	Dwarf sedge	70	70	25
Forbs and Dwarf Shrubs				
Achillea millefolium L.	Yarrow	45	—	—
Antennaria Howellii Greene	Everlasting	35	10	—
Antennaria umbrinella Rydb.	Everlasting	—	—	40
Aster conspicuus Lindl.	Rough aster	95	20	—
Forbs and Dwarf Shrubs (*continued*)				
Arnica cordifolia Hook.	Arnica	80	80	15
Astragalus scrotinus A. Gray	Poison vetch	60·	—	—
Castilleja miniata Dougl.	Painted bush	50	5	—
Cornus canadensis L.	Bunchberry	5	60	—
Epilobium angustifolium L.	Fire-weed	15	70	20
Fragaria glauca (Wats.) Rydb.	Strawberry	70	60	20
Hieracium umbellatum L.	Hawkweed	55	—	—
Lathyrus ochroleucus Hook.	Peavine	80	—	—
Lilium parviflorum (Hook.)	Red lily	45	30	—
Linnaea borealis Holtz. var. *americana* (Rehder) Forbes	Twin flower	50	70	—
Pedicularis bracteosa Benth	Lousewort	10	80	80
Sibbaldia procumbens L.	Sibbaldia	—	—	60
Valeriana sitchensis Bong.	Valerian	—	15	55
Vicia americana Muhl.	American vetch	45	—	—
Arctostaphylos uva-ursi. Spreng.	Kinnikinnick	80	10	—
Berberis aquifolium Pursh.	Oregon grape	75	—	—
Vaccinium caespitosum Mich.	Dwarf blueberry	20	10	**80**
Vaccinium scoparium Leiberg.	Blueberry	5	**100**	**45**
Lupinus sp.	Blue lupin	25	80	90
Pyrola secunda L.	Wintergreen	35	70	10
Mosses and Lichens				
Brachythecium spp.	Moss	30	**100**	**80**
Polytrichum juniperum var. *alpestre* B.S.G. Bryol. Eur.	Hairy cap moss	15	**80**	**85**
Hypnum crista-castrensis L.	Feather moss	—	**30**	**?**
Peltigera canina Willd.	Foliose lichen	25	**80**	**80**
Cladonia fimbriata Fr.	Fruticose lichen	10	**80**	**85**
Cladonia gracilis Willd.	Fruticose lichen			

N.B. Frequency figure in bold type indicates dominance of the species in that zone.

ally, the forest vegetation is characterized by greater variety than are the grasslands. The pine, willow, rose, heath, grass and composite families are well represented. The number of species recorded as occurring with a frequency of 10% or more is 36 for the Montane, 35 for the Subalpine and 25 for the Upper Subalpine zone.

Most species are confined to one or at most two zones, although there are a few plants such as *Carex concinnoides*, *Arnica cordifolia* and *Epilobium angustifolium* which occur in all three associations.

The dominant trees of the Montane zone are Douglas fir, lodgepole pine and aspen. Several species of willow are common. Ponderosa pine occurs on warm dry slopes, mainly in the lower part of the zone. The principal shrubs are *Shepherdia canadensis* and *Rosa* spp., while *Spiraea lucida* occurs commonly. The dominant herb is *Calamagrostis rubescens* (pinegrass) which comprises about half the herbaceous cover. Other important herbs include *Carex concinnoides*, *Arnica cordifolia*, *Aster conspicuus*, *Astragalus serotinus*, *Fragaria glauca* and *Lathyrus ochroleucus*. Two dwarf evergreen shrubby species. *Arctostaphylos uva-ursi* and *Berberis aquifolium* are common. Mosses and lichens are not abundant.

In the Subalpine zone, the dominant trees at present are lodgepole pine, Engelman spruce, and subalpine fir in relative order of abundance. The principal shrubs are *Vaccinium membranaceum*, *Pachystima myrsinites* and *Lonicera involucrata*. The herbaceous cover is relatively sparse and is dominated mainly by a dwarf, blueberry, *Vaccinium scoparium*. Other common species include *Cornus canadensis*, *Fragaria glauca*, *Lupinus* sp., *Pedicularis bracteosa*, *Pyrola secunda* and *Linnaea borealis*. The mosses *Brachythecium* sp. and *Polytrichum juniperum* and the lichens, *Peltigera canina* and *Cladonia* spp. are abundant.

The vegetation of the Upper Subalpine zone consists of forest alternating with treeless openings dominated by herbaceous species. The principal tree in the forested portions is Engelmann spruce, while subalpine fir is less abundant. Lodgepole pine and aspen are rare in this zone. The shrub cover is poorly developed and consists mainly of dwarf willows. *Vaccinium scoparium* dominates in the herb layer, but not to so marked an extent as in the Subalpine zone. *Lupinus* sp., *Pedicularis bracteosa* and *Vaccinium caespitosum* are abundant. The moss and lichen cover is similar to that of the Subalpine association, but not so dense.

The treeless openings of the Upper Subalpine zone are of two types, one dominated mainly by forbs and dwarf shrubs, the other by grasses. In the first type the principal species is *Vaccinium caespitosum*, while *Antennaria umbrinella*, *Pedicularis bracteosa* and *Sibbaldia procumbens* are sub-dominant. The grass or "mountain meadow" type supports a dense turf dominated by *Danthonia intermedia* along with lesser amounts of *Carex spp.*, *Trisetum spicatum*, *Phleum alpinum* and *Sibbaldia procumbens*.

Each of the three zones has a number of characteristic species. Some of the more important of these in the Montane association are Douglas fir, *Spiraea lucida*, *Berberis aquifolium*, *Astragalus serotinus* and *Lathyrus ochroleucus*. Characteristic species of the Subalpine include *Pachystima myrsinites* and *Cornus canadensis*. In the Upper Subalpine characteristic plants include *Danthonia intermedia*, *Deschampsia atropurpurea*, *Vaccinium*

caespitosum and *Sibbaldia procumbens.* If the two divisions of the Subalpine zone be considered as comprising one major type, this would have as additional characteristic species, Engelmann spruce, subalpine fir and *Vaccinium scoparium.*

Life Forms and Seasonal Growth

The forest zones contain a greater variety of life forms than occur in the grasslands. The relative importance of the principal forms in each of the forest types is indicated in Figure 7. The outstanding feature of all three zones is the dominance of evergreen, coniferous trees. This life form is well adapted to the relatively low temperatures, short growing season and moderate precipitation of the higher altitudes of the Tranquille region just as perennial bunchgrasses are adapted to the warmer and drier conditions existing on the lower slopes. The typical form of the dominant conifers is altered considerably in the Upper Subalpine zone where they are relatively shorter with sharply tapering trunks.

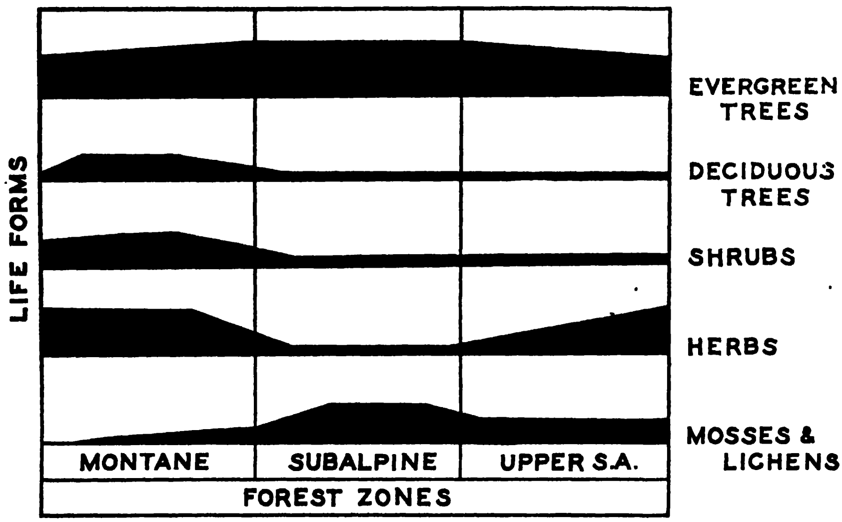

FIGURE 7. Relative Importance of Main Life-forms in forest zones of the Tranquille Range.

Shrubs flourish mainly in the Montane zone, where the tree cover is fairly open. In the Upper Subalpine the shrub form is assumed by several species of willow.

Grasses and other herbs grow well in both the Montane and Upper Subalpine associations, but are less vigorous and common in the dense shade of the Subalpine forest. Mosses and lichens thrive on the cool, moist and acid forest floor of this latter zone. Only the more xeric types of moss and lichen occur in the Montane association.

The period of growth starts later in each successively higher zone. Over a 4-year period the average date of first growth for the dominant species of the forest floor was April 22 for the Montane zone, May 12 for the Subalpine, and a week or more later for the Upper Subalpine. These

observations are in general accord with those obtained in similar zones farther south. Costello and Price (4) found that in the Wasatch Mountains of Utah the growing season begins 10 to 14 days later with each increase of a thousand feet in altitude.

Structure

The density of the forest increases from the relatively open stands formed by mature Douglas fir in the Montane zone to denser covers of spruce and fir in the Subalpine. In the Upper Subalpine the stands become thinner and are broken by numerous treeless tracts of considerable extent.

The density of the shrub cover decreases from the Montane to the Subalpine and shows little increase in the Upper Subalpine. Herbaceous vegetation is most abundant in the Montane and least in the Subalpine. With mosses and lichens the reverse is true.

Successional Relationships

The vegetation of all three forest zones has been subjected to repeated fires which have altered greatly the composition of the tree cover. In the Montane zone, many stands of Douglas fir have been destroyed and replaced by lodgepole pine and aspen. There is good evidence that with protection from fire, the fir will become dominant again by shading out the less tolerant pine and aspen. Since Douglas fir is a thick-barked species, many of the older individuals have withstood the ravages of fire and remained to serve as seed trees for new generations.

In the Subalpine zone, destruction of the thin-barked dominants, Engelmann spruce and subalpine fir, has been more complete. Over considerable areas in the Tranquille forest scarcely a spruce or fir occurs at present, the tree cover consisting almost entirely of lodgepole pine. Aspen is not nearly so abundant as in burned areas in the Montane zone.

Fires have occurred in the Upper Subalpine, although apparently not so often as in the lower forest zones. Lodgepole pine and aspen are rare in this association, and burned areas appear to be revegetated directly, although slowly, by the climax spruce and fir.

The composition of the shrub, herbaceous, and moss layers in the forest zones does not appear to have been altered greatly by the changes in tree cover resulting from fire. In some cases, as under aspen in the Montane zone, the herbaceous cover is denser and more luxuriant than in stands of climax timber, but the botanical composition is not changed significantly. This feature is of considerable importance in the recognition of zonal types in cases where the climax tree cover has been destroyed by fire and replaced by species such as lodgepole pine which are abundant in more than one zone.

The two types of treeless opening in the Upper Subalpine differ in successional status. The type dominated by forbs contains numerous remnants of charred wood, indicating previous occupation by forest. The presence of saplings appears to mark the beginning of re-occupation by forest. Restoration of tree stands must be very slow in this zone, for fires are not known to have occurred in the area for at least 20 years. The

grassland type of opening shows no signs of former forest occupation or present invasion of trees. Presumably it is a climax type under present climatic and soil conditions.

GRASSLAND SOILS

Profile descriptions

Brown Earths are to be found at the lowest elevation and they extend from 1100 to about 2300 feet. They are succeeded by Dark Brown Earths which occur as a belt between 2300 and 2800 feet, above which Black Earths carry through to the beginning of the forest soils. The upper limit of the Black Earths is about 3200 feet elevation.

The succession of soil zones follows the normal pattern, though as noted later, interesting variations occur with changing topography and exposure. The following descriptions are of profiles occurring in these three zones.

Brown Earth

Horizon	Depth	
A_1	0–10″	Brown loam, soft indefinite crumb structure, porous.
B_1	10–16″	Grey brown loam, hard and massive though softening slightly with depth, permeability is restricted. Lime concretions and pockets of gypsum crystals occur.
B_2	16–19″	Grey brown to bluish grey sandy loam, a partially weathered fragmentary glacial till, heavily impregnated with lime.
C	19″	Grey sandy loam, a strongly cemented glacial till, impervious to roots and moisture. No visible lime.

Dark Brown Earth

Horizon	Depth	
A_1	0–8″	Dark brown sandy loam, soft indefinite crumb structure, porous.
B_1	8–28″	Drab brown sandy loam, very dense, tough and massive with porosity greatly restricted. It is impregnated with streaks and specks of lime.
B_2	28–31″	Grey brown sandy loam, a partially weathered glacial till containing a heavy accumulation of lime.
C	31″	Grey brown sandy loam, a strongly cemented glacial till completely impervious.

Black Earth

Horizon	Depth	
A_1	0–8″	Very dark brown to black sandy loam, with a light floury texture.
B_1	8–18″	Dark brown sandy loam, dense and compact but not hard. Porosity is slightly restricted, lime specks occur.
B_2	18–24″	Grey brown sandy loam, a partially weathered glacial till with a heavy accumulation of lime.
C	24″	Grey brown sandy loam, a strongly cemented glacial till, containing no visible lime and impervious.

All profiles contain basaltic sub-angular gravel and stone.

Morphological Features

The most conspicuous features common to all three profiles are, *(a)* a shallow A_1 horizon, *(b)* a dense tough B_1 horizon, *(c)* a strong accumulation of free lime close to the surface, and *(d)* a strongly cemented, impervious C horizon. Each of these features plays a part in the development of the profile as a whole.

The depth of the A_1 horizon seldom exceeds 10 inches, even in the Black Earth zone. The shallowest soils are to be found on the crests of ridges, and the depth increases toward the toe of slopes. The average depth of the A horizon over the Tranquille Range is less than the average for relatively level sites where normal profile development should be expected to occur.

The shallowness is probably due to surface creep and sheet erosion. Sheet erosion was indicated by a piling up of soil material against the upper side of the crown of grass plants. Gully erosion occurs, but not to a marked degree. Since the entire area is a rolling hillside it is not surprising that shallow soils through erosion are a characteristic of the range.

A dense tough B_1 horizon is common to all zones but is most strongly developed in the Dark Brown Earth profiles. It is a feature of degraded profiles and has led the writers to suspect a solonetz development.

Mechanical analysis reveals that there has been a movement of clay for there is an accumulation of about 4% in the B_1 horizon of the Dark Brown Earths. The Brown and Black Earths show no such accumulation. The chemical analysis in Table 9 shows no movement of sesquioxides, however.

The pH of the B horizons of the Brown and Dark Brown Earths is high, but is not accompanied by any accumulation of sodium. Exchangeable sodium, shown in Table 10 does not exceed 1%. There is a high concentration of exchangeable magnesium, however, in the Brown and Dark Brown Earths and it is possible that this feature accounts for the dispersed, solonetz-like structure of the B_1 horizon in each zone.

The restricted porosity of the B_1 horizon in all three zones is an important factor in increasing the proportion of surface run-off water, which in turn accentuates sheet erosion.

An accumulation of calcium occurs in all three profiles. The depth varies from 10 inches in the Brown Earths to about 20 inches in the Black Earths. The accumulation of free lime, as shown by CO_2 analysis in Table 9 indicates a maximum concentration in the B_1 horizon of the Brown Earths, B_2 of the Dark Brown Earths and C horizon in the Black Earths.

The whole of the Tranquille Range area including both grassland and forest, is underlain by an extensive, strongly cemented glacial till, concrete-like in consistence. Similar tills are characteristic of several British Columbia series and also occur in Washington (18) where it has been suggested that the cementing action is due to secondary silica. This cemented feature of the parent material is associated with the geological origin and is in no way related to a pan formation.

TABLE 9.—ANALYSIS OF GRASSLAND SOILS OF TRANQUILLE RANGE

Soil zone	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Organic Carbon	Organic matter O.C.=1.724	N	CO_2	pH
		in.	%	%	%	%	%	%	%	%	%	%	%	%	
Brown Earth	A_1	0–10	59.45	8.10	12.93	3.55	2.83	2.37	2.37	0.27	1.75	3.02	0.19	0.09	7.89
	†		63.01	8.58	13.71	3.76	3.00	2.51	2.51	0.29					
	B_1	10–21	50.85	8.21	12.05	9.84	4.31	1.90	2.04	0.29	0.41	0.71	0.08	5.05	8.28
	†		53.39	8.62	12.65	10.33	4.53	1.99	2.14	0.30					
	B_2	21–27	50.64	8.74	11.76	8.59	5.09	1.73	2.41	0.27	0.27	0.47	0.03	4.57	8.25
	†		51.65	8.91	11.99	8.76	5.19	1.76	2.46	0.28					
	C	27–	53.54	9.08	12.98	7.31	4.62	1.89	2.70	0.26	0.34	0.59	0.02	4.05	8.33
	†		55.15	9.35	13 36	7.59	4.76	1.95	2.75	0.27					
Dark Brown Earth	A_1	0–8	56.93	8.55	13.20	4.00	3.57	2.09	2.56	0.31	2.10	3.62	0.25	0.06	8.18
	†		60.92	8.99	14.12	4.28	3.82	2.24	2.74	0.33					
	B_1	8–14	51.94	7.84	14.96	4.29	4.50	2.24	2.71	0.35	1.83	3.16	0.23	0.22	8.52
	†		55.58	8.39	16.00	4.59	4.82	2.40	2.90	0.37					
	B_2	14–29	45.89	7.73	13.65	12.47	4.28	1.40	2.42	0.35	0.56	0.97	0.04	7.25	9.41
	†		47.27	8.03	14.61	13.34	4.41	1.44	2.49	0.36					
	C	29–	50.48	8.44	13.75	9.11	4.39	1.94	2.73	0.32	0.30	0.52	0.02	4.68	9.05
	†		51.49	8.61	14.02	9.29	4.48	1.98	2.78	0.33					
Black Earth	A_1	0–8	47.11	9.34	11.96	5.14	6.17	2.27	2.34	0.50	5.20	8.96	0.58	0.04	7.10
	†		54.65	10.83	13.87	5.96	7.16	2.63	2.71	0.58					
	B_1	8–20	50.22	11.21	12.55	5.14	8.54	1.77	2.29	0.30	1.24	2.14	0.10	0.00	7.38
	†		52.73	11.77	13.18	5.40	8.97	1.86	2.40	0.31					
	B_2	20–30	49.14	9.73	11.21	7.10	10.00	1.38	2.30	0.24	0.79	1.36	0.06	1.67	8.39
	†		51.11	10.12	11.66	7.38	10.40	1.43	2.39	0.25					
	C	30–	47.55	13.98	19.31	4.11	2.83	1.29	1.79	0.34	0.56	0.97	0.04	2.03	8.50
	†		49.45	14.54	20.08	4.17	2.94	1.34	1.86	0.35					

† Calculated to mineral constituents only.

Chemical Characteristics

The total analysis of the grassland soils is presented in Table 9. These figures give a comparison of the genetic development occurring in one parent material under three climatic zones.

It will be noted first that the depth of calcium accumulation in the profile increases from the Brown Earth to the Black Earth. In the Brown Earth the greatest accumulation takes place between 10 and 21 inches, in the Dark Brown between 14 and 29 inches, and in the Black Earth between 20 and 30 inches. Magnesium behaves similarly to calcium but to a less exaggerated degree. The figures for carbon dioxide indicate that only a fraction of the divalent bases are present as carbonates and thus the parent minerals are probably rich in basic elements.

In the Black Earth zone the presence of increased amounts of calcium and magnesium without a corresponding carbon dioxide content would suggest that they are present in insoluble form. Their presence in such abundance may be due to an uneven mixture of the original basic minerals in the profile.

Silicates, sesquioxides and sodium appear to be relatively immobile.

Organic matter is highest in the Black Earths, and within the profile it tapers off gradually with depth. The total organic matter decreases from the Black Earth to the Brown Earths, but within the profile the organic matter tapers off sharply in the Dark Brown and Brown Earths with increasing depth.

The nitrogen figures follow the same trend as organic matter. The carbon-nitrogen ratio is about 9 in all three zones. Russell (15) quoting Remezov indicates that the ratio decreases from Black to Grey Desert soils.

Potash is richest in the A horizon of all three soils as a result of the decay of vegetation. It is an illustration of the natural conservation in grassland soils.

The Black Earths are distinctly richest in total phosphates, followed by Dark Brown and Brown Earths. Data on available phosphates shown in Table 10 show that they are present in reverse order to total phosphates, Brown Earths being richest and Black Earths poorest. It is apparent, therefore, that the high phosphate content of the Black Earths is largely unavailable. Dunnewald (8) reporting on the same soils described by Thorp (20) found available phosphates to be present in a similar order. These phosphate values appear to be high compared to Prairie soils of the same genetic type.

The pH values (Table 9) are interesting in that the unfavorable physical structure of the Dark Brown Earths is associated with a high degree of alkalinity. It will be noted that these values increase from pH 8.0 at the surface to pH 9.4 in the B_2 horizon. There is no significant accumulation of sodium. Exchangeable sodium, shown in Table 10, is higher in the B_1 and B_2 horizons than in the surface, yet quantitatively it is low. This leaves the relatively high magnesium content as the only source of the alkalinity. The high alkalinity probably causes a peptization of the soil colloids which contributes to the unfavorable structure of the B horizon.

TABLE 10.—EXCHANGEABLE BASES AND AVAILABLE PHOSPHATES IN THE GRASSLAND SOILS

Soil zone	Horizon	Mg. equivalents per 100 g. soil					Available P_2O_5
		Ca	Mg.	K	Na.	Total	
							p.p.m.
Brown Earth	A_1	12.5	5.5	0.7	0.2	18.9	813
	B_1	33.5	12.9	0.5	0.4	47.3	939
	B_2	54.2	9.5	0.4	0.6	64.7	754
	C	26.4	10.4	0.3	0.6	37.7	738
Dark Brown Earth	A_1	15.3	5.0	0.6	0.2	21.1	328
	B_1	14.6	8.0	0.8	0.8	24.2	257
	B_2	25.0	10.9	0.3	0.8	37 0	160
	C	24 3	9.9	0.2	0.3	34.7	1026
Black Earth	A_1	24.6	8.4	0.8	0.1	33.9	245
	B_1	11.8	5.5	0.5	0.1	17.9	199
	B_2	24.6	4.5	0.2	0.1	29.4	245
	C	28.9	5.5	0.1	0.1	34.6	226

Although the exchangeable bases are dominated by calcium, this ion does not exceed 80% of the exchangeable capacity; magnesium, on the other hand, is present at a relatively high concentration. There seems to be considerable evidence that the basaltic rocks from which these soils have been derived are high in magnesium minerals, and that this element has played an important part in the development of the grassland profiles.

Exchangeable potassium is concentrated in the surface horizons. It does not vary with zones.

The Black Earth A_1 horizon has the highest equivalent of exchangeable bases. This can be expected from the high organic content. It is surprising to find, however, that this abundance does not continue with depth. On the basis to the solum (A and B horizons), the Brown and Dark Brown profiles have a higher total exchangeable base content than the Black Earth profile.

FOREST SOILS

Profile Descriptions

Above the upper limit of the Black Earth soil there is an abrupt change to forested podsolic soils. Three distinctive profiles are encountered with increasing elevation. Each has its characteristic vegetation. For the purpose of this paper the profile occurring immediately above the Black Earth is called the Lower Podsol. It extends from 3200 feet to 4000 feet elevation. The second type extends from 4000 to 5800 feet and is called the Middle Podsol. The third profile occurs between 5800 and 6100 feet, the upper limit of the range and is called the Upper Podsol.

The most interesting feature of these profiles is that while all are definitely podsolic, each had independent and characteristic features. They have developed from a common glacial till, hence the morphological and vegetational changes that take place with increasing elevation suggest definite climatic zones. It is believed, therefore, that the characteristic

morphological features are a reflection of the relative intensity of the dynamic podsol producing system, as it occurs in each of these three profiles.

The following is a brief description of the profiles.

Lower Podsol

Horizon	Depth	
A_0	1½″	Dark brown organic mat, partially decomposed and fibrous.
A_2	0–2½″	Ash grey loam, gritty, structureless and porous.
B_1	2½–10″	Light yellow brown (creamy coloured) loam, amorphous and slightly dense.
B_2	10–25″	Drab brown clay loam, dense, tough, large angular nut structure.
C	25″	Grey brown loam, unweathered, strongly cemented glacial till. The top inch may contain free lime streaks.

Middle Podsol

A_0	1″	Dark brown organic mat, partially decomposed and fibrous.
A_2	0–1″	Ash grey loam, gritty, slightly compacted and structureless.
B_1	1–5″	Bright orange red sandy loam, single grained and porous.
B_2	5–15″	Drab brown loam, dense, tough prismatic structure.
C	15″	Grey brown loam, unweathered, strongly cemented glacial type, containing no visible lime.

Upper Podsol

Horizon	Depth	
A_0	3″	Dark brown to black organic mat, partially decomposed and contains many living roots.
A_2	0–4″	Dark iron grey sandy loam, single grained, high in organic matter.
B_1	4–11″	Dark orange brown sandy loam, single grained and porous. Contains much iron-humus coated gravel.
B_2	11–18″	Drab brown loam, slightly dense and weakly granular in structure.
C	18″	Grey brown loam, unweathered, strongly cemented glacial till.

All three profiles contain basaltic, sub-angular stones and gravel.

Morphological Features

The organic horizons of the Middle and Lower Podsols are similar in that both are fibrous, incompletely decomposed mor types. L and F horizons are distinct but the H horizon is superficial, seldom attaining measurable thickness. The organic layer is sharply differentiated from the mineral soil.

In the Upper Podsol the organic layer is also a mor type. There is a sparse litter layer intimately associated with a complete cover of living herbs, mosses and lichens. The F layer is deep, and while it is incompletely decomposed, it differs from the previous two types in that it is composed of finer, less woody fibre and is matted with living fine surface roots. Decomposition increases with depth but the transition to an H layer is indistinct. The organic matter penetrates into the mineral soil to a considerable depth. In the mineral soil the organic matter is finely

FIGURE 8. Fairly open stand of mature Douglas fir in Montane zone Note abundance and good growth of herbaceous vegetation.

FIGURE 9. Alternate forested and open areas in Upper Subalpine zone at an altitude of 6000 feet. The principal tree is Engelmann spruce, while the openings are dominated by grasses and sedges.

divided, much of it being colloidal especially below the A_2 horizon. Unlike a mull type of humus, no crumb structure is formed, the soil particles remaining single grained.

There is a well developed ash grey leached layer in both the Lower and Middle Podsols. In the former, the A_2 horizon is loose and dusty, while in the latter profile the leached layer is slightly compacted, whiter, and has the clean appearance of washed sand.

The A_2 horizon of the Upper Podsol resembles an A_1 in that it is dark coloured and high in organic matter. The chemical analysis, however, shows this layer to be leached of sesquioxides. It is probable that the ash grey colour has been masked by an organic coating.

The three podsol sub-types were largely identified and mapped by the conspicuous colours of the B_1 horizons. These colours changed from a lustreless yellow and grey brown to a bright orange red and finally to a dark orange brown, with increasing elevation. The change of colour from one zone to another was sharp and easily identified.

The structure was single grained in each case, except in the Lower Podsol zone where a weak fine crumb occurred.

The B_2 horizons of all three zones were characterized by an accumulation of clay, and the presence of a well defined structure There appeared to be no consistency in the relative amounts of accumulated clay between the different zonal profiles. The strongest structural development occurred in the Middle Podsol zone.

The occurrence of free lime as streaks over the impervious C horizon was a fairly consistent feature of the Lower Podsol. Free lime accumulation did not occur in the other podsol zones.

The Upper Podsol profile belongs to a sub-order that has been described as wet podsol, humus podsol, and mountain meadow soil. Joffe (11) described mountain meadow soils as a type of formation unique inasmuch as it has no equivalent in the horizontal zonal distribution of soils.

Three vegetation types are associated with the Upper Podsol zone. No profile differences were noted except that in the treeless meadow phase the A_0 and A_2 horizons were merged into a mineral horizon, very high in organic matter, but shallower than the combined A_0 and A_2 horizons of the forested phase.

In all three phases of the Upper Podsol, drainage was unimpaired except for the impervious C horizon, and there was no indication of a glei horizon. Numerous semi-bogs occur in the area with conspicuous glei horizons, but these form a distinct association not dealt with in this paper.

Chemical Characteristics

The fundamental difference between the Lower and Middle Podsols would seem to be associated with the nature of the organic matter, for most of the characteristic features can be explained on this basis. In the Lower Podsol zone there is a mixture of hardwood and softwood litter,

TABLE 11.—ANALYSIS OF PODSOL SOILS OF TRANQUILLE RANGE

Soil zone	Horizon	Depth in.	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	Organic carbon %	Organic matter O.C.×1.724 %	N %	CO_2 %	pH
Lower Podsol	A_0	2	48.21	5.17	8.35	2.58	3.10	0.94	1.18	0.15	11.97	20.64	0.46	Nil	5.82
	†		65.38	7.00	11.30	3.49	4.20	1.27	1.60	0.20					
	A_2	0–2½	63.67	5.98	13.28	2.66	2.83	1.93	1.97	0.16	1.63	2.81	0.09	Nil	6.48
	†		67.00	6.30	14.00	2.80	2.98	2.03	2.07	0.17					
	B_1	2½–8	60.06	7.56	14.97	2.95	2.24	1.50	2.04	0.21	0.99	1.71	0.08	Nil	6.24
	†		62.80	7.91	15.65	3.08	2.34	1.57	2.14	0.22					
	B_2	8–23	52.88	12.16	16.01	3.58	4.15	1.74	1.47	0.25	0.51	0.88	0.04	Nil	7.15
	†		54.90	12.60	16.60	3.72	4.30	1.80	1.52	0.26					
	C	23–	54.04	11.30	15.94	4.40	5.34	1.94	2.21	0.29	0.24	0.42	0.03	Nil	6.95
	†		55.70	11.65	16 42	4.54	5.50	2.00	2.27	0.30					
Middle Podsol	A_2	0–1	67.41	4.13	13.17	2.53	1.29	2.39	3.15	0.13	2.71	3.97	0.13	Nil	5.49
	†		72.60	4.45	14.20	2.73	1.39	2.58	3.40	0.14					
	B_1	1–5	51.08	9.08	18.54	2.68	1.45	1.92	2.63	0.84	3.82	6.69	0.17	0.02	5.88
	†		57.60	10.22	20.90	3.02	1.64	2.17	2.98	0.95					
	B_2	5–15	49.66	14.94	16.18	3.80	3.15	2.12	3.43	0.24	0.63	1.09	0.04	Nil	6.62
	†		51.50	15.50	16.79	3.94	3.26	2.20	3.56	0.25					
	C	15–	50.36	13.74	18.94	5.07	2.74	1.87	3.28	0.30	0.18	0.31	0.04	Nil	7.42
	†		51.51	14.10	19.40	5.20	2.80	1.92	3.36	0.31					
Upper Podsol	A_2	0–7	42.60	9.53	14.19	2.98	1.92	1.39	2.50	0.34	12.16	20.96	0.52	Nil	4.87
	†		54.60	12.20	18.20	3.82	2.46	1.78	3.20	0.44					
	B_1	7–14	46.32	13.69	18.54	4.26	2.70	1.64	2.89	0.32	2.78	4.79	0.17	Nil	5.60
	†		50.60	14.90	20.30	4.66	2.95	1.79	3.16	0.35					
	B_2	14–21	46.68	13.79	19.96	4.40	2.69	1.60	3.25	0.39	0.88	1.52	0.06	Nil	6.05
	†		48.80	14.40	20.82	4.60	2.86	1.67	3.39	0.41					
	C	21–	52.49	13.18	18.09	4.55	4.65	1.77	3.08	0.43	0.25	0.43	0.03	0.05	7.05
	†		53.90	13.50	18.60	4.68	4.79	1.82	3.16	0.44					

† Calculated to mineral constituents only.

plus the annual accumulation from a luxurious herbaceous cover. The decomposition of such material will produce a humus of relatively high base status. The organic layer of the Middle Podsol profile has been derived from a coniferous forest, in which hardwoods are absent. The understory of shrubs and herbs is sparse.

It is to be expected, therefore, that the decomposition products will form a raw acid humus. This supposition is borne out in several respects by the chemical analysis shown in Table 11. The degree of acidity is shown to be appreciably greater in the Middle Podsol profile. Further, it will be noted that the organic matter in the Lower Podsol zone has not been eluviated to the same extent as in the Middle Podsol zone. In the former case organic matter decreases quickly with depth, indicating a stable colloidal form, while in the latter case organic matter accumulates in the B_1 horizon from a dispersed state.

Dispersed humus colloids through their protective action influence the leaching of iron oxide. Reference to Table 11 shows the leaching of sesquioxides to have taken place in all three profiles, and in respect to the two first profiles, it is quite apparent that eluviation is greatest in the Middle Podsol zone. The relative amount of sesquioxide to silica is shown in Table. 12. It will be seen that the B_2 is the horizon of greatest accumula-

TABLE 12.—SILICA SESQUIOXIDE MOLECULAR RATIO IN MINERAL CONSTITUENTS OF FOREST SOILS

Soil zone	Horizon	SiO_2/R_2O_3	SiO_2/Fe_2O_3	SiO_2/Al_2O_3
Lower Podsol	A_0	7.0	24.6	9.8
	A_2	6.3	28.4	8.1
	B_1	5.1	21.0	6.8
	B_2	3.8	11.5	5.6
	C	4.0	12.7	5.7
Middle Podsol	A_2	7.2	43.0	8.6
	B_1	3 5	14.9	4.7
	B_2	3.3	8.8	5.2
	C	3.1	9.7	4.5
Upper Podsol	A_2	3.5	11.7	5.1
	B_1	2.9	8.9	4.2
	B_2	2.8	9.0	4.0
	C	3.3	10.5	4.9

tion. A comparison of the Lower and Middle Podsols shows the latter soil type to have suffered the greatest losses of iron and aluminium from the A_2 horizon.

The analysis of exchangeable bases is shown in Table 13. It will be noted that the Lower Podsol contains a greater number of base equivalents

TABLE 13.—EXCHANGEABLE BASES AND AVAILABLE PHOSPHATES IN FOREST SOILS

Soil zone	Horizon	Mg. equivalent per 100 g. soil				Available P_2O_5
		Ca	Mg	K	Total	
						p.p.m.
Lower Podsol	A_0	15.3	8.4	0.7	24.4	174
	A_2	5.7	3.5	0.5	9.7	80
	B_1	5.7	3.5	0.5	9.7	110
	B_2	12.5	10.9	0.3	23.7	429
	C	11.1	10.9	0.2	22.2	697
					65.3	
Middle Podsol	A_2	3.6	1.0	0.2	4.8	72
	B_1	5.7	2.0	0.3	8.0	192
	B_2	10.0	5.0	0.2	15.2	292
	C	12.5	6.5	0.2	19.2	875
					47.2	
Upper Podsol	A_2	2.4	1.0	0.2	3.6	24
	B_1	1.8	0.5	0.1	2.4	29
	B_2	7.1	2.0	0.1	9.2	229
	C	11.4	5.0	0.1	16.5	1203
					31.7	

than the Middle Podsol profile, indicating the importance of the base status of the humus layer as a source of supply. These figures illustrate the degree of leaching in two ways, first by the depletion of bases from the A_2 horizon and second, by the depth of the accumulation zone. The A_2 of the Lower Podsol appears to be less leached than the Middle Podsol and the horizon of accumulation is the B_2. In the Middle Podsol, accumulation occurs in the C horizon. The intensity of leaching is greatest, therefore, in the Middle Podsol zone.

Unfortunately Table 13 does not show the base exchange capacity, hence it is impossible to compare the degree of saturation of the two soils. For the same reason no comments can be made on the organic versus inorganic colloids, or on the destruction of the absorbing complex through the leaching of sesquioxides.

The analytical data show that the influence of the humus base status on soil reaction, degree of dispersion, and intensity of leaching is most important. This feature should be of prime significance in determining podsol sub-zones.

The Upper Podsol appears to be differentiated from the others on the basis of a lack of weathering rather than intensity of leaching.

The climatic conditions are somewhat tundra-like in that the soil is snow covered and frost bound for nearly nine months of the year, and

summer frosts are frequent. Such conditions are not conducive to physical, chemical or biological action. This is well brought out by the analytical data.

In the first place the high organic content of the A_0 and A_2 horizons suggests that biological decomposition cannot keep pace with the annual accumulation. The A_0 horizon is a 3-inch organic mat, while from Table 11 it will be seen that the A_2 horizon contains nearly 21% organic matter. That this is a raw acid humus is shown by the pH values (Table 11). It will also be noted that the movement of organic matter persists to great depths.

In respect to the eluviation of sesquioxides it will be noted from Table 11 that accumulation has taken place in both B_1 and B_2 horizons, whereas in the other podsol types accumulation occurred mainly in the B_2 horizon. The suggestion that a lack of physical and chemical weathering is a feature of this zone is amplified by the figures for sesquioxide movement. The amount is small compared to the Middle Podsol profile. This is in spite of a low pH value and a raw acid humus layer, the conditions favouring intensive leaching. The figures in Table 12 show that while sufficient leaching has taken place to indicate podsolization, the differentiation between the A and C horizons is slight.

From Table 13 it will be seen that exchangeable bases are very low and tend to accumulate in the C horizon. The high organic content of A_2 must be extremely unsaturated for such low values to be attained. The depth to which organic matter is carried and the accumulation of exchangeable bases in the C horizon suggest the intensity of leaching to be greatest in the Upper Podsol zone. However, from the slight movement of sesquioxides it must be concluded that podsolization in this zone is restricted by the short season during which active weathering may take place.

Pearson (9) found that forest soils in Arizona tended to be deepest in the lower zones, weathering being hampered by low temperatures at higher altitudes. Soils in all zones above the ponderosa pine association tended to be thin and relatively coarse in Arizona. On the Tranquille range, the soils of the Montane zone are as deep and well developed as those of the zones below, and only in the Upper Subalpine is there any marked decrease in profile development.

The pH values found by Pearson under conditions of vertical zonation in Arizona were 8.2 in the top 6 inches of grassland soil, 7.0 in the Douglas fir (Montane) zone, and 6.5 in the Engelmann spruce (Subalpine) zone. These values correspond fairly closely to those determined for the soils of the Tranquille area (Tables 9 and 11).

SOIL-PLANT ZONAL BOUNDARIES

The boundaries between both soil and plant zones were fairly distinct and no wide transition belts occurred. These boundaries follow the contour of the land remarkably closely where the exposure is uniform.

Grassland Zones

The limitations of grassland soil zone distribution due to exposure are interesting. Brown Earths are to be found chiefly on south and west

exposures. Gently sloping north and east exposures in the Brown Earth zone are characterized by an invasion of Dark Brown Earths. On the south side of the Kamloops valley, Brown Earths having a northerly exposure occur. Their upper limit, however, is about 300 feet below the average level on south and west slopes.

A similar invasion of Black Earths into the Dark Brown Earth zone occurs on gentle north and east slopes.

The best development of the Black Earth profile is to be found on gently sloping and level ground. Crests and ridges are frequently very dark brown rather than black in colour. Where north and east exposures occur on steep slopes there is an abrupt change to forested podsol soils.

It has already been noted that the succession of soil zones on mountainous grasslands is more or less similar to that of level topography. The boundaries are governed by elevation rather than latitude. In this respect Thorp (20) provides an interesting comparison for a similar succession in Wyoming.

	Big Horn, Wyoming	Tranquille, British Columbia
Brown Earth	5000–5500 feet	1100–2300 feet
Dark Brown Earth	5500–6500 feet	2300–2800 feet
Black Earth	6500–7700 feet	2800–3200 feet

The Big Horn Range is at Latitude 44 while the Tranquille Range is at 51, a difference of 7 degrees of latitude.

Plant zonation in the grasslands shows the effect of slope and exposure in much the same manner as do the soils. The vegetation of each association tends to intrude into that of the zone above on warm, dry slopes and to extend into the zone below on cool, moist exposures. Depressions in the Middle Grassland zone are occupied usually by Upper Grassland species including Kentucky bluegrass and graceful sedge and have a Black Earth profile. Forest vegetation extends well into the Upper Grassland zone on North and east slopes.

Pine Savanna

A marked variation of the normal zonal succession occurs on the east side of the Tranquille River (Figure 1) at an altitude of 2100 to 3000 feet. Here a ponderosa pine savanna occurs immediately above the Lower Grassland association and below the Montane zone. The Middle and Upper Grassland types are not present in this area. The soil in the pine savanna closely resembles the Dark Brown Earth usually associated with Middle Grassland vegetation. Black Earths do not occur.

The vegetation of this type consists of ponderosa pine forest with a well developed ground cover dominated by perennial bunchgrasses, mainly bluebunch wheatgrass, rough fescue and Junegrass. The tree stand is extremely open at the lower edge of the zone and its density increases gradually with altitude to the point where it merges with the Montane forest. A similar vegetation and soil complex has been noted in several portions of Southern British Columbia, including the Thompson, Nicola and Okanagan valleys. This association appears to represent the northern

fringe of the ponderosa pine zone which occupies extensive areas farther south in the Rocky Mountain region.

No detailed study was made of the factors responsible for the occurrence of this type. No marked difference in soil conditions was apparent, although on the average soil texture was a little coarser, stones more plentiful and pH a little lower than for comparable grassland soils. The pine savanna is most common on fairly coarse soils, often at the foot of steep slopes where seepage from above tends to increase sub-soil moisture. Apparently the type is associated with a climatic tension zone between forest and grassland, and its presence or absence seems to be determined by relatively small local differences in climate and soils.

Forest Zones

Only a brief study was made of the influence of exposure upon the distribution of soils in the forested region, as the area is relatively inaccessible and served by only two pack trails. One feature noted was that the best development of the Upper Podsol occurs on the rolling plateau at the highest elevation. This may be an influence of exposure and topography, but on the other hand it is possible that the maximum development occurs only at 6000 feet and over.

As in the grassland area, local conditions of slope and exposure affect zonal boundaries. The Montane forest ascends 300 or more feet above its normal altitudinal limits on south and west slopes. Conversely, the Subalpine zone descends considerably along narrow stream valleys where the topography tends to produce moister and cooler conditions.

The most striking feature of zonation in the Upper Subalpine is the occurrence of treeless openings, often called "mountain parks" (6). As noted earlier, some of these are potential forest sites, recovering slowly from destruction by fire. There still remain many openings occupied by grasses and grass-like plants where there is no evidence of past occupation by forest or present trend in that direction. The vegetation is low growing, and is characterized by a number of alpine species, including mountain hairgrass, alpine timothy and sibbaldia. The soils of the openings appear to be essentially similar to those of the forested portions of the zone.

Similar mountain parks in the Subalpine zone have been described by investigators in the Rocky Mountain region, and various theories have been advanced to account for their occurrence. Poor soil aeration and a microclimate unsuitable for tree growth are common explanations. Although drainage is good in the openings in the Tranquille Subalpine zone, the sharpness of the line between forest and treeless areas suggests that edaphic factors may be involved. In addition, the microclimate of the openings may differ enough from that of the remainder of the zone to affect plant life critically. Dixon (7) who found a similar vegetation at high altitudes in Utah, points out that these openings, being located in basins and shallow valleys, tend to be cooler and moister than adjacent areas.

Zonation in Other Areas

Brief studies of grassland areas in other parts of southern British Columbia indicated that the zonal sequence found on the Tranquille range

is of general occurrence. In the Kamloops district and in the Nicola and Okanagan Valleys to the south and southeast of Kamloops, marked agreement was found in the nature of both soils and vegetation. The altitudinal limits of the zones varied with local topographic and climatic conditions.

Less opportunity was afforded for soil-plant studies of forest vegetation in other areas. Limited observations indicated that, as in the case of the grasslands, the zonal types found on the Tranquille Range are of general occurrence in southern British Columbia.

SOIL-PLANT RELATIONSHIPS

Climatic Influences

The marked changes in climate occurring at different altitudes on the Tranquille Range were discussed in the introduction of this paper. It was noted that moisture conditions are the principal factors limiting growth at lower altitudes, including all the grassland zones.

Data concerning the relationship of the atmospheric moisture conditions to soil composition and plant production are presented in Table 14.

TABLE 14.—P/E RATIO IN RELATION TO PLANT YIELD AND SOIL NITROGEN

Soil plant zone	P/E ratio	Forage yield per acre	Soil nitrogen of A horizon
		lb.	%
Brown Earth Lower Grassland	6.4	375	0.19
Dark Brown Earth Middle Grassland	10.0	560	0.25
Black Earth Upper Grassland	20.0	1200	0.58

The P/E ratio is generally considered to be one of the best indices of the external moisture conditions affecting plant life (12). It is apparent that on the Tranquille grasslands both plant production and soil fertility are affected greatly by moisture conditions. From Table 14 it is evident that with an increasing precipitation efficiency there is a denser vegetation and under natural conditions, a more fertile soil.

Some data were obtained on soil moisture reserves at the beginning of the growth periods of 1939 and 1940. A comparison of these figures with the depth of the layer of lime accumulation is shown in Table 15.

TABLE 15.—AVAILABLE SOIL MOISTURE AND DEPTH OF LIME ACCUMULATION

Soil plant zone	Available soil moisture				Depth of lime layer
	0–6 ins.	6–12 ins.	12–18 ins.	18–24 ins.	
	%	%	%	%	in.
Brown Earth Lower Grassland	7.3	6.0	1.9	0.5	10
Dark Brown Earth Middle Grassland	17.5	8.1	3.7	2.1	14
Black Earth Upper Grassland	24.6	10.8	10.0	9.8	20

The depth of the lime accumulation is evidently a good indication of the lowest depths of appreciable soil moisture, in so far as plant roots are concerned. This is brought out in Table 9 also where the depth of organic matter, largely decayed roots, is shown to coincide with the depth of useful amounts of soil moisture.

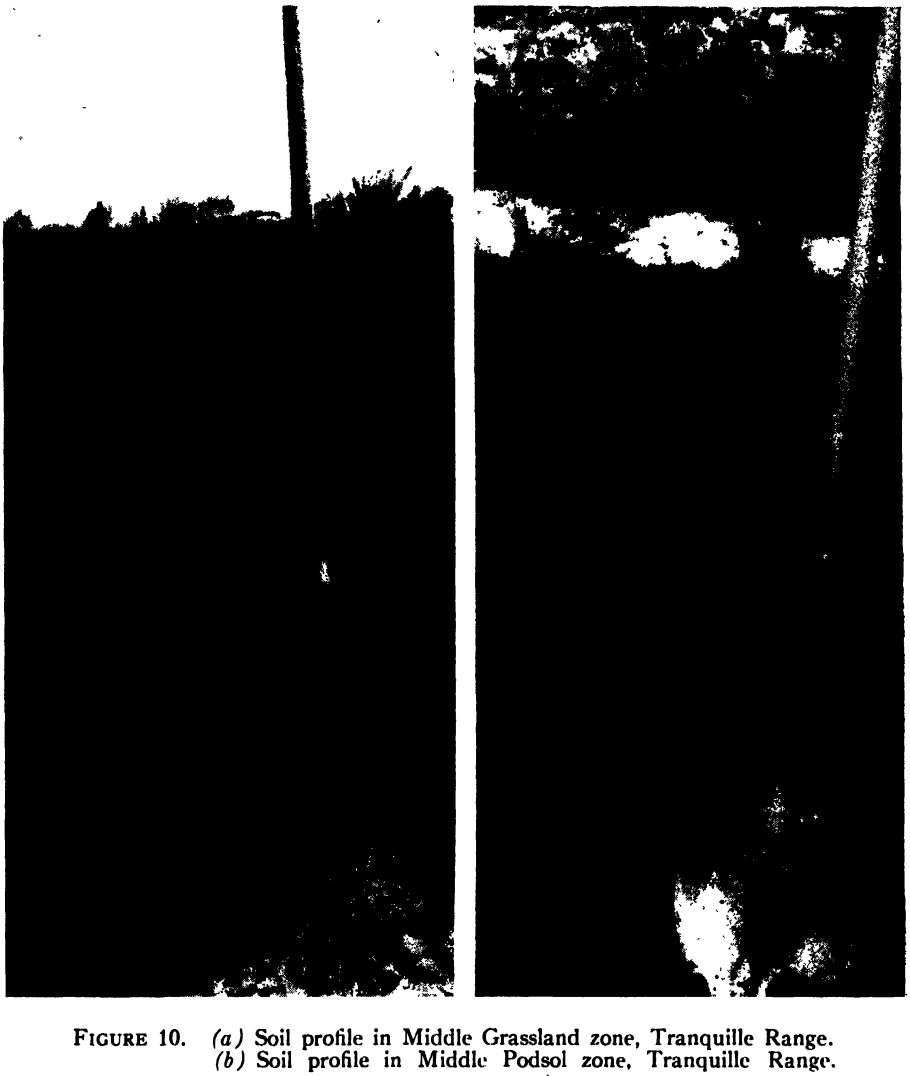

FIGURE 10. *(a)* Soil profile in Middle Grassland zone, Tranquille Range.
(b) Soil profile in Middle Podsol zone, Tranquille Range.

In the Montane zone, as in the grasslands, moisture conditions are of prime importance. The growing season is still sufficiently long for the full seasonal development of a varied flora, while soil moisture is often deficient particularly in the late summer. In the Subalpine and Upper Subalpine types, however, temperature seems to be the dominant factor. Soil moisture is usually abundant, but shortness of growing season and low air and soil temperatures restrict plant and soil development. According to

Thornthwaite's (19) system of climatic classification, the Subalpine zone is in the "Taiga" class in which low temperature efficiency is the major limiting factor. The Montane zone is classified in the "Microthermal" group, coolest of those climates in which precipitation effectiveness is still the prime factor.

The climatic conditions prevailing in the Montane zone are reflected in the presence of a fairly open cover of coniferous and deciduous trees, along with the development of a rich shrub and herb flora. This vegetation in turn influences soil development, through the medium of a relatively high lime humus, with production of the characteristic Lower Podsol profile.

In the Subalpine, climate favours the production of a fairly dense stand of coniferous trees with a sparse understory of shrubs and herbs and a well developed ground cover of mosses and lichens. This in turn results in the formation of a raw, acid humus and a soil profile in which leaching is more pronounced than in the Lower Podsol.

In the Upper Subalpine, temperatures are still more extreme, while evaporation is probably greater than in the Subalpine. Conditions are less unfavourable for tree growth, with the result that the vegetation consists of patches of relatively dwarfed coniferous forest interspersed with treeless openings. The soil profile formed under these conditions is characterized by a high content of organic matter in the surface horizons and by a lack of weathering.

Soil-Plant Relationships within the Zones

Within the grassland zones, the soil characteristics of most importance in respect to the plant cover were those associated with the moisture factor. Depth of the solum appeared to be of outstanding importance in this regard. The vegetation of shallow soils was characterized by the presence of xeric species and by sparse cover and poor growth.

Slight differences in soil texture had no apparent effect on the plant cover, but marked differences affected both species composition and productivity. Very fine soils were rare on the study area, but sandy and gravelly types were fairly common. Species associated with these coarse soils included sand dropseed, three-awned grass (*Aristida longiseta*), Indian ricegrass (*Oryzopsis hymenoides*), sumach (*Rhus glabra*), balsam root and *Erigeron compositus*.

A number of the dominant species were good indicators of soil conditions. Sagebrush, for instance, occurred widely in the Lower Grasslands, but formed tall, dense stands only on soils of good depth and moisture content. Kentucky bluegrass and Columbia speargrass, although co-dominant over much of the Upper Grassland zone, differed considerably in habitat requirements. The bluegrass dominated on low-lying areas of deep soil and good moisture conditions, while the speargrass was most abundant on drier sites with relatively shallow, coarse soils. Bluebunch wheatgrass was dominant on practically every type of soil in each of the three zones. However, there were marked differences in density, height and yield depending on soil depth and texture. Clipped plots of this species in the Lower Grassland zone yielded 67% more forage on a site with a fairly deep loam soil than on an area with a shallow, sandy loam profile.

Soil reaction did not appear to be strongly significant. In the Lower and Middle Grasslands some surface soil ratings were as high as pH 8.4 with pH 9.4 in the C horizon. These alkaline conditions had no marked effects on the distribution of plant species but appeared to cause some reduction in plant cover and production.

In the forest, variations in soil conditions within the zone were not marked in the relatively limited area covered by the study. Shallow, gravelly soils were indicated by open stands and poor growth of trees and by the abundance of such ground cover species as kinnikinnick. In general, aspen was most abundant on soils of relatively good depth and fine texture.

Range Utilization in Relation to Vertical Zonation

It has been pointed out that there is a succession of climatic changes from the lowest to the highest elevations on the Tranquille Range and in southern British Columbia generally. As a result of these climatic differences there is a vertical zonation of vegetation and soils.

In the utilization of range lands, vertical zonation must be taken into account in any program which aims at securing maximum use of grazing resources without depletion. The characteristics of the various zones in relation to grazing use are discussed briefly in the following section.

In the Lower Grassland zone, bluebunch wheatgrass is the principal species. On the Tranquille Range (21) the average date of first growth is mid-March. The readiness for grazing stage (plants averaging 6 inches in height) is reached a month later. Active growth is usually finished by the end of June, and curing follows in July or August. Fresh fall growth supplements the dry forage in most years. This is the least productive of the grassland zones.

The Middle Grassland zone is similar in many ways to the Lower Grassland type. Bluebunch wheatgrass and common speargrass are the principal forage species. Growth begins about 10 days later than in the lower zone and curing is correspondingly delayed. The grazing capacity is greater than at lower elevations, but only about one-half that of the Upper Grassland zone.

The Upper Grassland type contains a variety of forage species of which bluebunch wheatgrass, rough fescue, Columbia speargrass and Kentucky bluegrass are the principal forms. Growth begins nearly two weeks later than in the Middle Grasslands and the date of readiness for grazing is correspondingly later, averaging about mid-May. Much of the forage usually remains green during the entire summer. This is the most productive of the grassland zones, with a grazing capacity three times as great as that of the Lower Grassland type.

The Montane forest zone provides a considerable amount of grazing due to the presence of a well developed understory of shrubs and herbs. Pine grass constitutes half or more of the available forage, but many broad-leaved plants including rose, spiraea, rough aster, hawkweed, lupin, peavine and vetch are eaten. Growth begins later than in the grassland zones, and the readiness for grazing stage is not reached until mid-June. The yield of forage is approximately the same as for the Lower Grassland and

the grazing capacity is probably similar, although not much is known at present of the long-term productivity of timber ranges.

The Subalpine zone is in general unsuited for grazing as the herb and shrub cover is relatively sparse and contains a high proportion of unpalatable species. The Upper Subalpine type is better adapted to grazing, due to a greater abundance of forage and to the presence of treeless openings. Since the growing season is short, the period of use is confined mainly to July and August. Sheep are often grazed in both the Upper Subalpine and Alpine zones.

It is evident that the natural grazing sequence for a range containing vertical zones should be based upon the occurrence of successively shorter seasons of growth and cooler climate at higher altitudes. The marked differences in grazing capacity of the various zones need to be considered also.

A suitable grazing plan for a range such as the Tranquille would involve using the Lower Grassland zones from mid-April to early May and the Middle Grasslands until the end of May. The Upper Grasslands would be utilized during June and the Montane Forest from late June until the end of September. In October the Upper Grassland zone would be grazed again, followed by the Middle and Lower Grasslands in November and on into the winter if sufficient forage were available. A grazing program similar to this was carried out on the Tranquille Range (21) for several years with marked benefits to both vegetation and livestock.

Where proper range use is not practised, depletion of vegetation and soils is bound to occur. On the Tranquille grasslands, marked changes in plant cover and considerable soil erosion have occurred as a result of improper grazing for a period of nearly 60 years. Overgrazing has resulted in a great decrease in the abundance and vigour of the perennial grasses and a corresponding increase in unpalatable species. The details of the provess vary with each zone.

The most striking change produced by overgrazing in the Lower Grasslands has been the decrease in abundance and vigour of bluebunch wheatgrass and the increase in sagebrush. Dwarf everlasting, pasture sage and cactus have increased also.

Most of the perennial grasses of the Middle Grassland zone have decreased greatly with overgrazing, but dwarf bluegrass (*Poa secunda*), due to its short stature and low palatability, has not been affected as much as more desirable species. Weed species which have increased greatly include downy bromegrass, rabbit brush, pasture sage and dwarf everlasting.

The vegetation of the Upper Grasslands is less readily affected by overgrazing than is that of the two lower zones and the changes have been less drastic. Two of the dominants, bluebunch wheatgrass and rough fescue have declined greatly with overgrazing, but the other two, Columbia speargrass and Kentucky bluegrass have persisted to a surprising degree. Unpalatable forms which have increased include species of everlasting, fleabane and dandelion.

Grazing of the forest zones of the Tranquille Range has not been sufficiently heavy to produce significant changes in plant cover. On this range, as in many others in southern British Columbia, the grazing resources

of the forest zones were not utilized to any extent until quite recently. At the same time it is apparent that misuse of the timber ranges would result in deterioration of the forage cover.

In relation to soil conservation, overgrazing is a serious cause of erosion, ample evidence of which was found on the Tranquille grasslands. On both grassland and forest ranges, destruction of the plant cover leads not only to erosion but also to drought through accelerated run-off and a general lowering of the water table. When the balance between soil, vegetation and climate is upset by the misuse of land, a vicious cycle commences that ends with the destruction of the soils ability to maintain vegetation. The Lower and Middle Grassland zones in particular, due to the dry, warm climate under which they exist, are highly susceptible to the ill effects of overgrazing.

SUMMARY

The observations obtained from a soil plant survey of the Tranquille Range in the southern interior of British Columbia are presented, together with analytical data in support of the findings.

The study was confined chiefly to an area having a general southerly exposure and a range in elevation from 1100 feet to 6100 feet.

It was found that temperature and the frost-free period decrease while precipitation and the P/E ratio increase with increasing elevation.

Associated with these climatic changes was found a succession of soil and plant zones.

The agreement between the respective soil and plant zones was sufficiently close to establish a definite relationship. These zones are as follows:

Altitude	Soil Zone	Plant Zone
1100–2300 feet	Brown Earth	Lower Grassland
2300–2800 feet	Dark Brown Earth	Middle Grassland
2800–3200 feet	Black Earth	Upper Grassland
3200–4000 feet	Lower Podsol	Montane Forest
4000–5800 feet	Middle Podsol	Subalpine Forest
5800–6100 feet	Upper Podsol	Upper Subalpine

The genetic development of the soil and the corresponding plant cover show that moisture is the most important climatic influence at lower elevations. There is a close agreement between plant growth and the precipitation-evaporation ratio.

With increasing elevation, temperature and the length of the frost-free period are the decisive factors determining zonal development.

The influence of elevation and exposure on the distribution of vegetational and soil zones is described.

The grassland zones are dominated by perennial bunchgrasses, particularly bluebunch wheatgrass (*Agropyron spicatum*) and belong to the Palouse Prairie Formation. The Lower Grassland type is characterized by a sparse cover, low productivity and the abundance of xeric forms such as sagebrush (*Artemisia tridentata*) and sand dropseed (*Sporobolus cryptandrus*). The Upper Grassland zone is distinguished by a richer flora,

denser cover, greater productivity and the common occurrence of relatively mesic plants such as Kentucky bluegrass (*Poa pratensis*) and graceful sedge (*Carex praegracilis*). The Middle Grassland zone is intermediate in nature between the other two types.

The forest zones are dominated by evergreen conifers. The Montane forest is characterized by stands of Douglas fir (*Pseudotsuga taxifolia*), by well-developed shrub and herb layers and by sparseness of the moss and lichen cover. The Subalpine type is distinguished by denser stands in which Engelmann spruce (*Picea Engelmanni*) and subalpine fir (*Abies lasiocarpa*) are the climax dominants. The shrub and herb strata are sparse but the moss layer is well developed.

The Upper Subalpine zone is occupied by alternating areas of forest and treeless openings. Engelmann spruce is the principal tree, while oat-grass (*Danthonia intermedia*) dominates in the openings.

The important morphological features of the grassland soils are, a shallow solum probably due to erosion and surface creep, a dense, tough solonetz-like B horizon, a high concentration of free lime close to the surface and an impervious glacial till subsoil.

The chemical data indicate that besides calcium, magnesium is present in unusually large amounts. It is suggested that the solonetz-like B horizon may be due to magnesium rather than sodium.

The podsol soil sub-zones are distinguished by the characteristic colours of the B_1 horizon. These are yellow brown, bright orange red and orange brown.

It is suggested that the genetic difference between the Lower and Middle Podsols depends largely upon the base status of the humus layer, while the Upper Podsol is differentiated by a short annual period of active weathering rather than a less intensive leaching.

The relation of vertical zonation to range utilization is discussed briefly and the changes resulting from overgrazing in the grassland zones are described.

CONCLUSIONS

The project has shown that within a limited geographical unit, a close agreement exists between soil and plant zones. To a limited extent it was shown that the texture, depth and reaction of soils within a zone may be identified by the composition and abundance of the plant cover. Similarly, much can be deduced from soil studies regarding the potential plant cover of areas on which the vegetation has been temporarily altered by factors such as grazing or fire. As a consequence the writers are of the opinion that minute as well as broad relationships may be found between the soil and the plant cover it supports.

The data indicate that both plant communities and certain characteristic species are good indicators of the habitat. The dominants of an association do not by their presence alone serve as precise indicators, since they usually extend throughout a broad type or, as in the case of *Agropyron spicatum*, may dominate in more than one zone. Density, yield and vigour are of prime importance in assessing the indicator value of dominant species.

The writers are enunciating no new theory in expressing the belief that soil and plant studies are complementary and, with experience, may be used to mutual advantage in gaining a fuller understanding of both these natural resources. These conclusions are in agreement with those of Shantz (11), Cajandar (3) and others who have found close relationships between soil and vegetation and have put these findings to practical use in land utilization, forestry, etc.

Joint soil-plant surveys seem especially suitable for broad reconnaissance work where lack of detail in the mapping of soils and vegetation may be offset by better understanding of relationships between the various types.

For range surveys, soil-plant studies are a means of describing zones, their capabilities and limitations for man's use in a most effective and practical manner. Where vertical zonation of vegetation and soils occurs, proper grazing utilization can be secured only by management practices based on the nature and relationship of the different zones. Neglect of this principle results in depletion of both vegetation and soil.

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PLANT TISSUE TESTING[1]

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The chemical examination of plants as a means of determining the availability of soil nutrients and thus, indirectly, the fertilizer requirements of a crop, has long been advocated by certain workers. In 1928, Salter and Ames (2), after a study of the Neubauer seedling method, the analysis of juice from plant tissues, and Hoffer's tissue test for nitrogen and potassium, reached the conclusion that this method of approach to the problem was not of very much practical use. However, since that time, a large amount of work has been done on the use of plant analysis or tissue tests by a number of workers. Various modifications of the general methods of examining the plant itself are available, such as the foliar diagnosis procedure of Thomas (5), the spectrographic analysis method of Lundegårdh (1), the examination of plant sap, etc. Such methods involve quantitative laboratory analyses and require considerable time. A promising, relatively rapid, semi-quantitative method has been developed by Thornton *et al.* (6), and applied with apparently good results by Scarseth (3, 4).

While the longer laboratory methods are necessary in certain types of research, the more rapid semi-quantitative test which distinguishes between abundant and deficient amounts of nutrients, if found to be workable, would be satisfactory in diagnosing the fertilizer needs of a crop. In the method of Thornton, the amounts of unassimilated nitrate, inorganic phosphate and potassium in the plant tissue are measured. The tests are carried out in the following way: (a) For nitrates, a solution of diphenylamine in concentrated H_2SO_4 is applied to the plant tissue. A dark blue colour develops when nitrates are present. (b) For phosphates, the plant tissue is cut into small pieces and extracted with a solution of ammonium molybdate in HCl. When stannous chloride is added, a blue colour develops if phosphate is present. (c) For potassium, the plant tissue is cut into small pieces and extracted with a solution containing sodium cobaltinitrite, sodium nitrite and acetic acid. When ethyl alcohol is added and the solution let stand, a yellow precipitate separates out due to the presence of potassium. The interpretation of the tests is made on the basis of very high, high, medium, low and very low values, depending on the depth of colour developed by the tests.

A preliminary investigation of the application of the Thornton method was conducted on the fertilizer plots of the Division of Chemistry, Central Experimental Farm, Ottawa, during 1943. Here it was possible to compare the results of the tissue tests with the effect of fertilizer treatments on yields. An area consisting of 4 ranges was available, each range containing 2 blocks of 5 plots each. The soil was a light sandy loam, classified as Uplands sand, and had been cropped with vegetables for a number of

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years. Five treatments were used, viz., check, PK, NP, NK and NPK, which, on the 4 ranges of 2 blocks each, gave 8 replicates of each treatment. The individual plots were 1/200 acre in size. The fertilizers used and the amounts applied per plot were as follows: nitrogen as sulphate of ammonia, 1 lb.; phosphorus as 20% superphosphate, 2 lb.; potassium as muriate of potash, 1 lb. These quantities together corresponded to a mixed fertilizer of 4-8-10 composition at the rate of 1000 lb. per acre. Three kinds of plants were grown, potatoes (3 rows), tomatoes (1 row of 4 plants), and corn (2 rows).

The first part of the growing season was characterized by heavy and frequent rainfall. The appearance of the plants indicated a possible lack of nitrogen which might have been due to leaching. It was therefore decided to repeat the application of sulphate of ammonia on those plots which had received it previously.

From early in the summer, the crops showed definite response to the nitrogenous fertilizer but not to those supplying phosphoric acid and potash. The plants on all plots which received treatments of nitrogen showed much more vigorous growth than those on the other (check and PK) plots. One row of corn on each plot was used for plant tissue tests, the other being kept for yield. One row of potatoes was used for testing and the yield was measured on the other two. With the tomato plants, only one leaf from each plant was used in the testing so that all could be used for obtaining yield data.

The figures showing the yields, expressed on the basis of pounds per acre, are presented in Table 1. They show very clearly that there was little if any effect from the PK treatment but that a very striking increase was obtained on all plots receiving nitrogen. The differences between the NP, NK and NPK treatments were small. In general, applications of sulphate of ammonia doubled the yields. Thus these results have substantiated the observation, made on the appearance of the growing crop, that the response to the nitrogenous fertilizer was very marked.

Tissue tests were made only once during the season, over the period July 19-23. As recommended in the method, the petiole of a leaf from the middle of the main stem of tomato plants, and the base of the main stalk of potato plants were used for all the tests. With corn, the nitrate test was applied to the base of the main stem, the phosphate test to the growing tip of the main stalk or the main stalk just below the tassel, and the potassium test to the base of the leaf at the ear node or near the middle of the stalk. Each individual tomato plant was sampled and nitrates were determined on each leaf petiole, but a composite sample from each plot was used for the phosphate and potassium tests. For potatoes and corn, one stalk from each plot was selected and, since there were 8 replicates, this gave 8 stalks from each treatment. The results obtained for each plot, together with the average results for each treatment and the relative yield (check = 100) are presented in Tables 2, 3 and 4 for tomatoes, potatoes, and corn, respectively.

On the tomatoes, the tests showed that nitrates were low in the plants grown on the check and PK treatments, but the levels were raised to medium and high where nitrogen was applied. On the other hand, the

phosphate test, although showing an average value of high and medium for the plants grown on the check and PK treatments, was only medium on the NP and low on the NK and NPK plots. This may have indicated that an insufficient supply of phosphate was available when growth was increased by nitrogen applications. The potassium tests showed satisfactory levels in practically every plant tested.

With the potato crop, the nitrates were low or very low in the plants from the check and PK plots. However, the application of the nitrogenous fertilizer corrected this deficiency and raised the average of the plots to high or very high with only an occasional individual low test. The phosphate tests were very high on the check and PK plots where growth was poor; they gave an average high reading on the NP and NPK plots where good growth was obtained but only a medium average on the NK treatments where no phosphatic fertilizer was added and where growth was also good. The tests for potassium were very high for each individual plant examined.

The nitrates in the corn plants remained low or very low throughout except for an occasional stalk where nitrogen had been applied. Phosphate levels appeared in general to be satisfactory, though a number of low tests were obtained on individual plants on the nitrogen-treated plots where there was increased growth. Potassium was found at an average high level regardless of treatments.

In general, the plant tissue tests have agreed fairly well with the yield results. Nitrates were definitely deficient in the plants grown on the check and the PK-treated plots, but they were increased considerably, when a nitrogenous fertilizer was added, in the tomato and potato plants but not in the corn plants. Apparently the corn crop was still not getting sufficient nitrogen. There was also an indication that more phosphatic fertilizer should have been applied, along with the nitrogen, for the tomato crop.

The results obtained in this preliminary study of the application of Thornton's method of plant tissue testing have been rather interesting and have shown some relationship with the figures for the yields obtained from a number of fertilizer treatments. Considerable variation among individual plants has been shown and this has served to indicate the degree of accuracy that may be expected and has acted as a guide to the general interpretation of results. A sufficient number of plants from each plot should be taken to give an average value to represent that plot. This study has shown that the method has possibilities sufficient to warrant further investigation. It is hoped that this may be carried out in 1944.

TABLE 1.—YIELDS OF TOMATOES, POTATOES AND CORN

Treatment	Yields*		
	Tomatoes	Potatoes	Corn
	lb.	lb.	lb.
Check	22320	6540	4680
PK	22080	6780	4920
NP	53640	14160	11520
NK	61800	14100	10920
NPK	63840	14460	11280

* Yields in lb. per acre.

TABLE 2.—TISSUE TESTS ON INDIVIDUAL PLOTS—TOMATOES

Test	Range and block	Check	PK	NP	NK	NPK
	R5B1	L	L-M	H	L-M	VH
	B2	VL	L	H	M	M-H
NO_3	R6B1	L	L	M	M-H	M-H
	B2	L	L	M-H	H	M-H
	R7B1	L	VL	L	M	M
	B2	L	L-M	H	H	H
	R8B1	L-M	M	M-H	L	L-M
	B2	M	VL	VH	H	VH
	Average test	L	L	H	M	H
	Relative yield	100	99	242	278	287
	R5B1	VH	VH	H	L	L
	B2	M-H	L	L	VH	L
	R6B1	VH	VH	M	L	L
	B2	VH	L-M	L	VL	L
PO_4	R7B1	VH	H	L	L	L
	B2	L-M	L	M	VL	L
	R8B1	VH	VH	M	L	L
	B2	L	L	M	VL	VL
	Average test	H	M	M	L	L
	Relative yield	100	99	242	278	287
	R5B1	VH	VH	VH	VH	VH
	B2	VH	VH	VH	VH	VH
K	R6B1	VH	H	M	VH	H
	B2	M	H	H	H	VH
	R7B1	VH	M	H	VH	VH
	B2	L	L	H	VH	VH
	R8B1	VH	VH	H	VH	VH
	B2	VH	M-H	H	VH	VH
	Average test	H	H	H	VH	VH
	Relative yield	100	99	242	278	287

TABLE 3.—TISSUE TESTS ON INDIVIDUAL PLOTS—POTATOES

Test	Range and block	Check	PK	NP	NK	NPK
	R5B1	L	VL	H	H	H
	B2	VL	VL	VH	VH	VH
NO_3	R6B1	VL	VL	M	H	H
	B2	VL	VL	VH	H	VH
	R7B1	VL	VL	H	L-M	VL
	B2	VL	VL	VH	VH	L-M
	R8B1	VL	VL	VH	H	H
	B2	VH	VL	VH	M	H
	Average test	L	VL	VH	H	H
	Relative yield	100	104	217	216	221
	R5B1	VH	VH	M-H	M	M-H
	B2	H	VH	M-H	M	M-H
PO_4	R6B1	VH	VH	M-H	H	M-H
	B2	VH	H	H	H	M
	R7B1	VH	VH	M	M-H	H
	B2	H	M-H	M	L	H
	R8B1	VH	VH	H	H	H
	B2	M-H	VH	M-H	M	M
	Average test	VH	VH	H	M	H
	Relative yield	100	104	217	216	221

TABLE 3.—TISSUE TESTS ON INDIVIDUAL PLOTS—POTATOES—*Concluded*

Test	Range and block	Check	PK	NP	NK	NPK
	R5B1	VH	VH	VH	VH	VH
	B2	VH	VH	VH	VH	VH
K	R6B1	VH	VH	VH	VH	VH
	B2	VH	VH	VH	VH	VH
	R7B1	VH	VH	VH	VH	VH
	B2	VH	VH	VH	VH	VH
	R8B1	VH	VH	VH	VH	VH
	B2	VH	VH	VH	VH	VH
	Average test	VH	VH	VH	VH	VH
	Relative yield	100	104	217	216	221

TABLE 4.—TISSUE TESTS ON INDIVIDUAL PLOTS—SWEET CORN

Test	Range and block	Check	PK	NP	NK	NPK
	R5B1	VL	VL	L	VL	L-M
	B2	VL	VL	VL	VL	VL
NO_3	R6B1	VL	L	VL	VL	VL
	B2	VL	VL	VL	VL	H
	R7B1	VL	VL	VL	VL	VL
	B2	VL	L	H	H	VL
	R8B1	VL	VL	VL	VL	VL
	B2	L-M	VL	H	VL	H
	Average test	VL	VL	L	VL	L
	Relative yield	100	105	246	233	241
	R5B1	H-VH	H-VH	L	L	L
	B2	VH	H-VH	H-VH	VL	M
PO_4	R6B1	VH	VH	H-VH	L	M-H
	B2	M-H	M	M-H	M-H	H
	R7B1	H	VH	L	L	VH
	B2	H	VH	M	H-VH	H
	R8B1	H	VH	L	H	VH
	B2	VH	H	M-H	H-VH	H-VH
	Average test	H	VH	M	M	H
	Relative yield	100	105	246	233	241
	R5B1	H	H	M	H	H
	B2	H	H	H	VH	M-H
K	R6B1	M	VH	H	H-VH	H-VH
	B2	H	M-H	M-H	H	H
	R7B1	L-M	M	H	M-H	H
	B2	M	H	M	M	VH
	R8B1	VH	VH	VH	VH	H
	B2	M-H	H	M	VH	M
	Average test	H	H	H	H	H
	Relative yield	100	105	246	233	241

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THE EFFECT OF VARIOUS DIETS ON GROWING PIGS

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In another place we (1) have published the results of experiments on the effect of various diets on the susceptibility of pigs to *Salmonella suipestifer* infection. Briefly, under the conditions of our experiments, conducted in Eastern and Western Canada, the cultures employed were toxigenic and a few pigs died after an actue condition following the administration of culture by mouth, but in no instance did necrotic enteritis develop. The primary object of the experiment was to determine what effect, if any, the various diets would have on susceptibility, and the results of feeding on the growth and development of the animals was only briefly discussed. In this paper our object is to present such feeding data as was obtained and to introduce only such of the other phase of the experiment as is necessary to explain the results. We do wish to emphasize, however, that this is only the by-product of the other work and has no pretension to having been conducted as a feeding experiment. The data may be of some interest on account of the background of the work.

I. REPLACEMENT OF ANIMAL PROTEIN WHOLLY AND IN PART BY SOYA BEAN OILMEAL

Fifteen pigs about 8 weeks of age were arranged in groups of 3. These animals had been obtained from 2 litters on the same premises and were only 1 day apart in age. They were weaned at 7 weeks. The pigs were so grouped that the total weight of each group was between 61 and 63 lb. They were identified by metal ear tags. Each group had access to a small dirt run which was devoid of all vegetation.

The basal ration employed throughout this experiment consisted of oat chop 40%, wheat and barley chop 30% each, ground limestone 1% and iodized salt 0.5%. When alfalfa or other green feed was unobtainable, and this was usually the case, feeding oil in the recommended amounts was provided daily. The diets for the 5 groups were as follows:—

Group 1. Basal ration and feeding oil.

2. Basal ration, oil and 10% tankage.

3. Basal ration, oil and sufficient soya bean oilmeal to bring the protein to the same level as No. 2.

[1] The first experiment was conducted at the Branch Laboratory, Lethbridge, Alta., and the second and third at the Animal Diseases Research Institute, Hull, Quebec.
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4. Basal ration, oil and sufficient of a 50-50 tankage-oilmeal mixture to maintain the same protein level as groups 2 and 3.
5. Basal ration, oil and a 75-25 tankage-oilmeal mixture to maintain the same protein level as groups 2, 3 and 4.

Soya bean oilmeal contains about 36.5% protein whereas tankage contains not less than 50% so that, in order to have the same amount of protein in each lot, groups 3, 4 and 5 were fed such quantities of the supplements as would allow for the difference in protein of each mixture.

The tankage was cut from 10% to 8% when the average weight of all the hogs was approximately 60 lb. and to 6% when the average weight approximated 100 lb. The other supplements were reduced to maintain the same protein levels as the tankage. They were maintained at the last level until the hogs were marketed.

During the first 168 days of the experiment, the pigs were regularly weighed and a close check was maintained on group feed consumption. The original and final weights, the gain in pounds, the average daily gain of individuals and groups and the feed consumption per pound of gain are shown in Table 1.

TABLE 1.—GAINS AND FEED CONSUMED IN LB. OVER A PERIOD OF 168 DAYS

Group	Pig	Original weight	Weight 168 days	Gain	Group gain	Gain per pig/day	Group gain per day	Cost per lb. gain in cents for 112 days
1	932 933 937	18 28 16	103 190 90	83 162 74	321	0.50 0.96 0.44	1.91	7.4
2	938 939 940	16 21 25	203 203 192	187 182 167	536	1.11 1.08 0.99	3.19	6.3
3	941 942 974	23 23 16	210 224 174	187 201 158	546	1.11 1.19 0.94	3.25	9.8
4	975 976 977	20 25 16	190 237 195	170 212 179	561	1.01 1.26 1.06	3.34	8.2
5	978 979 980	27 18 18	233 235 210	206 217 192	615	1.22 1.29 1.14	3.66	8.5

It will be seen from Table 1 that the largest gains were made by Group 5 which received the 75-25 oilmeal-tankage supplement. However, the cheapest gains were made in group 2 in which tankage alone was employed. The next cheapest gains were in Group 1 on the basal ration, but this group only represented 383 lb. against 598 in the next smallest group. No attempt was made to establish the minimum amount of each concen-

trate required as we were only concerned with having groups receiving no additional protein and sufficient protein to maintain good growth. The cost is based on basal ration $29.45 per ton, feeding oil $3.90 per gallon, tankage $3.50 per cwt. and soya bean oilmeal $9.50 per cwt. The group gains made by each of the supplement groups are relatively close, there being a difference of only 79 lb. between the highest and lowest of these.

While the gains for group 5 were highest at the finish, followed by Groups 4, 3, 2 and 1, this order was not maintained throughout the experiment as is shown by the percentage gain of each group over the original weight at 28-day intervals. This is given in Table 2.

TABLE 2.—PERCENTAGE GAIN OF EACH GROUP AT 28-DAY INTERVALS OVER THE ORIGINAL WEIGHT OF THE GROUP

Group	Days					
	28	56	84	112	140	168
	%	%	%	%	%	%
1	33.4	61.3	140.3	261.3	391.9	517.7
2	52.1	125.8	309 7	538.7	759.7	864.5
3	68.6	167.7	337.1	491.1	682.3	880.6
4	62.4	142.6	290.2	482.0	711.4	919.7
5	65.1	157.1	341.3	541.3	766.7	976.2

It will be seen from Table 2 that the pigs in Group 3 made the highest gain during the first 56-day period. On the 84th day the greatest gain over the starting weight was recorded for group 5, from which time this group maintained the lead. The lowest gain, as was to be expected, was consistently recorded for Group 1. The second position was held by Group 5 for the first 56-day period, by Group 3 at the 84th day weighing, by Group 2 on the 112th and 140th days and by Group 3 on the 168th day.

There were variations in health prior to and following exposure to infection but, as the infecting doses of *S. suipestifer* were not commenced until the 184th day, the results of these have no bearing on the feeding results. The pre-infection variations, however, do influence the results. On the 32nd day, No. 933 in Group 1 developed respiratory symptoms and loss of appetite; it had recovered again by the 45th day. In spite of the set-back, this animal made better daily gains over the 168-day period than the other two in the group.

On the 46th day, No. 939 in Group 2 was scouring. It was treated and returned to the group in 5 days. No. 979 in Group 5 developed similar but milder symptoms and recovered in 36 hours.

During the period from the 98th to 112th days the food consumption of the pigs in Group 3 fell away greatly. They appeared normal in all other respects but made the smallest gain of any of the 5 groups during this period. The weights of each group for the 2-week periods are shown in Table 3.

TABLE 3.—GAIN IN WEIGHT OF GROUPS 1 TO 5 AT INTERVALS OF 2 WEEKS

Group	Days					
	1 - 14	14 - 28	28 - 42	42 - 56	56 - 70	70 - 84
	lb.	lb.	lb.	lb.	lb.	lb.
1	10.0	10.0	4.5	13.5	16.0	33.0
2	18.0	13.0	22.5	24.5	48.0	66.0
3	20.5	22.5	27.0	34.0	45.0	60.0
4	15.0	23.0	20.5	28.5	34.0	56.0
5	13.5	27.5	28.0	30.0	51.0	65.0

Group	Days					
	84 - 98	98 - 112	112 - 126	126 - 140	140 - 154	154 - 168
1	36.0	39.0	40.0	41.0	45.0	33.0
2	71.0	71.0	80.0	57.0	50.0	15.0
3	58.0	38.0	64.0	54.0	62.0	61.0
4	49.0	68.0	68.0	72.0	71.0	56.0
5	68.0	58.0	61.0	81.0	78.0	54.0

As the experiment approached the 152nd day the food consumption of Group 2 was considerably lower than that of the other groups. On the 154th day, No. 939 in Group 2 again developed diarrhoea and had a temperature of 103.8, which persisted for a couple of days. *S. suipestifer* was recovered from the faeces of this animal. On the 160th day, No. 940 in this group had a slight elevation of temperature and loss of appetite. The hogs in this group had not returned to normal until the 167th day. Feed consumption was approximately 100 lb. less than any of the other groups during the 154–168-day period and this was reflected in the gain for that time. No. 939 gained only 2 lb. and No. 940 neither gained nor lost.

Table 3 further shows that for the first 70 days the greatest bi-weekly gain alternated between Groups 3 and 5. From the 70th to the 126th day Group 2 showed the largest gain. From the 126th to the 154th day Group 5 again showed the highest gain and during the last 2 weeks this position fell to Group 3. With the exception of Group 3 in the 98–112 day period and Group 2 in the 154–168 day period, the lowest bi-weekly group gain was made by Group 1.

Briefly, for the first 168 days of this experiment the highest gains were recorded for Group 5 which received the 75-25 oilmeal-tankage supplement, followed by Groups 4, 3, 2, and 1, which were 50-50 mixture, soya bean oilmeal alone, tankage alone, and no supplement, respectively. For comparable gains, Group 2 (tankage alone) was the most economical and Group 3 (soya bean oilmeal) the most expensive.

II. BASAL RATION AND VARIOUS SUPPLEMENTS

On April 16, eight groups of 4 pigs each were assembled in a cement-floored, well-lighted stable in pens 10′ × 6′. The pigs had been obtained from 3 sources and had been weaned from 1 to 3 weeks. Care was taken

to have each source represented in a pen so that, as far as possible, the groups would be similar. All were tagged for identification and the males were castrated. These animals were put on various diets with the object of determining whether these would have any effect on the susceptibility of the different groups to infection with *S. suipestifer*. Since this was not in any way intended as a feeding experiment, the only concern being with the effect of diet on susceptibility, the feed was not weighed. The pigs were fed as much as they would clean up in a reasonable time, at first 3 times a day and later twice.

Owing to difficulty in obtaining some of the supplements, these animals received a 40-30-30 mixture of oat, wheat and barley chop until May 11. From that time they received equal parts of oat, wheat and barley chop, 1% of salt and the following supplementary substances:—

Group 1 Basal ration only (Diet A).
2. Basal ration with 1% limestone (Diet B).
3. Basal ration, limestone and 10% tankage (Diet C).
4. Diet C and 5 cc. feeding oil per pig/day (Diet D)
5. Diet D and 1 oz. dried brewers yeast per day.
6. Diet D and 100 mg. of nicotinic acid per pig/day.
7. Diet D and 1.5 grams iron sulphate per pig/day.
8. Diet D with NaOH solution once daily.

The tankage in Groups 3 to 8 was gradually reduced to 5%. Yeast and nicotinic acid were included because so much has been written regarding their use in the prevention and treatment of necrotic enteritis. Iron was used against the possibility of sub-clinical anaemia. It was at first given in capsules but was later incorporated in the feed. Sodium hydroxide was introduced because it had proved to be of value in checking necrotic enteritis under field conditions and it was desired to see whether it would have any preventive value and if it had any harmful effects. Since none of the pigs became infected the former point remained unsettled and, under the latter, there did not appear to be any bad effects, unless a somewhat lower haemoglobin content of the blood could be ascribed to its use. The stock solution consisted of 1 lb. of Gilletts lye in 1 gallon of soft water. One fluid ounce of this was added to 1 gallon of water and one feeding a day was mixed with this solution. Water was used for the other feedings. All groups were fed wet.

The details of this experiment have been reported in the previous paper and need not be repeated here except as necessary to explain what occurred in the various groups. They were all exposed to infection by mouth with 24-hour broth culture of *S. suipestifer* on July 27, August 25 and 31, September 8, 14, 16, 22, and 27. The first dose gave rise to very severe symptoms and 2 pigs died. One of these was in Group 2 and the other in Group 5. The subsequent doses produced little or no effect.

The pigs were weighed on April 19, May 11, July 7, August 10, and between October 18 and 30. The weights of the groups in April, May and October, the average daily gain per pig from April 19 to May 11, and the average daily gain of these animals from May 11 to the end of the experiment in October, are shown in Table 4.

TABLE 4.—WEIGHTS OF GROUPS 1 TO 8 AND AVERAGE DAILY GAIN PER PIG FROM APRIL 19 TO MAY 11 AND MAY 11 UNTIL END OF EXPERIMENT

Group	Weight			Average daily gain per pig	
	April	May	October	April–May	May–October
	lb.	lb.	lb.	lb.	lb.
1	109	133	570	0.27	0.63
2*	75	101	556	0.39	0.89
3	113	161	931	0.54	1.14
4	86	112	949	0.29	1.26
5*	69	90	714	0.31	1.26
6	110	145	951	0.39	1.23
7	137	177	988	0.45	1.26
8	109	156	966	0.53	1.26

* Based on 3 pigs, as 1 in each of these groups died following the first exposure to infection.

During the first 22 days, when the pigs were on a diet of grain only, the average daily gain per pig for the different groups varied from 0.31 to 0.54 lb. This was due to some extent, although not altogether, to the difference in size of the pigs. Roundworms probably played some part. No effort was made to treat the animals as it was desired to leave the worms for the purposes of the experiment. The period from May to October, shows an increased daily gain for the pigs that received the added protein. The addition of yeast, nicotinic acid, iron sulphate and NaOH solution in groups 5, 6, 7, and 8, respectively, made no appreciable difference to the results. Group 3 did not receive feeding oil and was slightly behind the others but this was more noticeable in the smoothness of the pigs than in the daily gains.

Twenty of the surviving 30 pigs were slaughtered, 10 sows being kept for future experimental work in connection with resistance to infection. Necropsies on the 20 animals were performed at time of slaughter. One animal in Group 3 had arthritis in one tarsal joint. There was a history of injury but the condition may have been due to lack of Vitamin A. Twelve animals had roundworms ranging in number from 1 to 75. All were otherwise negative.

III. CORN WITH AND WITHOUT TANKAGE COMPARED WITH REGULAR DIET

In connection with endeavours to infect pigs with *S. suipestifer* some were put on corn diets. Sixteen pigs were divided in groups of 4 animals each. The first 3 groups were from the same source and feeding was commenced on September 23. The fourth group was introduced on October 2 and these 4 pigs were from a different source than the others. The diets were as follows:—

Group 1. Equal parts oat, wheat and barley chop, tankage 10%, limestone 1%, NaCl 0.5% and 5 cc. feeding oil per pig/day.
2. Corn meal, tankage 10%, limestone 1%, NaCl 0.5% and feeding oil.
3. Corn meal, limestone, NaCl and feeding oil.
4. Corn meal, limestone and NaCl.

Group 4 was added to try the effect of leaving out any outside source of Vitamin A. Richter and Rice (2) have shown that there was loss of appetite and activity in rats on an exclusive corn diet and that these animals scarcely maintained their starting weight. In the case of Group 4 it should be noted that the pigs were obtained from a different source and were not as good as Groups 1 to 3.

In the course of the experiment, the pigs were exposed to infection with *S. suipestifer* by the administration of broth cultures of this organism on 2 occasions and half of them were exposed to sub-zero temperatures for 52 hours. The sudden change from the comparative comfort of the pig stable had no apparent effect on these animals.

These pigs were killed in February. Two animals in Group 4 had non-specific lung and pleural infections but the others were essentially negative. Roundworms varied in number from none to 115. The groups were commenced at 2 different times and were killed at different times in February so that no very exact comparison can be made. However, the weights and average daily gains from commencement to time of slaughter are shown in Table 5.

TABLE 5.—WEIGHTS OF GROUPS AND AVERAGE DAILY GAINS OF PIGS IN EXPERIMENT 3

Group	Sept. 23	Oct. 2	Nov. 2	Feb.	No. of days	Average daily gain per pig/day
	lb.	lb.	lb.	lb.		lb.
1	111	–	202	667	155	0.89
2	132	–	200	598	155	0.75
3	129	–	159	380	137	0.45
4	–	108	92	206	126	0.19

The first three groups in Table 5 are strictly comparable as the pigs came from the same source and were commenced at the same time. Group 1 on mixed grain and tankage did better than group 2 on the corn and tankage diet, but the great difference was between these groups and groups 3 and 4. As already pointed out, group 4 was from a different lot of pigs but, even allowing for this, the difference in gains was too great to be merely due to this factor.

SUMMARY

During the 168-day period recorded in Experiment 1, the highest gains were made by the group on the 75-25 soya bean oilmeal-tankage supplement, followed by the groups which had received 50-50 oilmeal-tankage, soya bean oilmeal alone, tankage alone and no supplement, respectively. For comparable gains, the tankage group was the most economical and the soya bean oilmeal group the most expensive. The differences in the gains of any of the supplement groups was not very large but there was a great difference between these groups and that on the basal ration only. It is generally recognized that a mixture of proteins

is better than a single one, which was borne out in this experiment, although any of the mixtures, apart from cost, might have been satisfactorily employed.

In Experiment 2, the two groups that did not receive any protein supplement were considerably behind the tankage groups. The addition of yeast, nicotinic acid, iron sulphate and sodium hydroxide solution made no noticeable difference to the tankage groups. One group, which received tankage but no feeding oil was slightly behind the others but this was more appreciable in smoothness than in daily gains.

In Experiment 3, in which 1 group received oat, wheat and barley chop and the other 3 corn meal, the best gains were made by the chop, tankage, limestone, salt and oil group, with the corn meal, tankage, limestone, salt and oil group next. There was a considerable drop in the group that had corn meal, limestone, salt and oil, and a very great difference in the group on corn meal, limestone and salt without feeding oil. Unfortunately this last group was from another source than the first 3 groups but the difference in gains appeared to be too great to be attributed to this factor alone.

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PARTHENOCARPIC FRUIT PRODUCTION IN HORTICULTURAL PLANTS[1]

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The 1942 and 1943 fruit blossoming seasons in many parts of Canada were characterized by cold, rainy weather, and the few sunny periods were cold enough in some districts to restrict the activities of pollinating insects. Recent reports on the artificial induction of seedless fruits in vegetables and ornamentals by Gardner and Marth (1), Gustafson (2, 3, 4, 5), Varrelman (7), and Wong (8), gave rise to speculation as to whether or not plant hormones might be utilized to induce the set of seedless apples, especially during spring periods when natural pollinating conditions were not good.

Briefly, the modern technique of inducing parthenocarpy consists of applying some substance to the female reproductive organs (stigma, style or ovary) of the flower. For a positive reaction, the substance so stimulates the ovary that normal swelling of the ovary and receptacle takes place in the absence of actual fertilization. Natural substances, such as talc and pollen extract, have been used with some success, but the most outstanding results have been secured by Gustafson (2, 4), Howlett (6), Wong (8) and others, using various plant hormone chemicals. These hormone substances (sometimes termed "phytohormones" and "growth substances") are now produced commercially as aids in rooting plant cuttings, and preventing pre-harvest fruit drop. The chemicals most used for such purposes have been such acids as indoleacetic, indolebutyric, indolepropionic, naphthaleneacetic and phenylacetic. In addition, salts and acetamides of some of these acids have been found to be active as plant hormones. A new compound, naphthoxyacetic acid, has been shown to be quite active for inducing parthenocarpy (4), but a supply could not be secured for the work reported here.

The hormones may be applied to the flower parts in solution (as sprays) or in paste form combined with a non-injurious carrier such as lanolin (sheep's wool fat). In addition to these commonest methods, hormones have sometimes been injected into the flower ovary, or vaporized in a tight compartment where the plants are growing (9).

MATERIALS AND METHODS

Preliminary trials to note the effect of indolebutyric acid (I A)[3] and naphthaleneacetic acid (N A)[3] on petunia, potatoes and tomatoes, were conducted under glass during the winter and spring of 1943. Lanolin paste and aqueous solutions of the materials were used at varying concentrations. The paste was applied to stigmas, to the ovary apex where style has been broken out, to the base of individual flowers, and to the

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[3] These abbreviations will be used hereinafter.

cluster base in plants having flowers borne in clusters. Almost all flowers were emasculated in the bud stage, and treatments were made from one to three days later, usually when the stigmas were in a receptive condition.

For outdoor trials, apple flowers alone were used, and for all treatments except the power-spraying of entire trees, the individual flowers were emasculated and in most cases the clusters were bagged to prevent the intrusion of any pollen or aphis stimulus.

RESULTS

Petunia

Sixty flowers were treated either at the ovary, the stigma or the flower base. Twenty-two fruits, seedless, and varying from 35% to 50% of normal size, were harvested. Ovary applications of either NA or IA with lanolin as a paste carrier were the most successful treatments. Concentrations of hormones thus successfully used were from 0.1% to 5.0%. Flowers sprayed with NA 1.0% were quickly killed. Flowers pollinated with another petunia variety produced normally seeded fruits, but the wrinkled parthenocarpic fruits induced with hormones were filled with minute, empty seed coats.

Potatoes

Of 134 Earlaine potato flowers treated with hormones, only 7 seedless fruits were produced. These were about one-third normal size, and contained no seeds. Their locules were filled solidly with pulp. Applications of NA (1.0% and 5.0%) lanolin paste produced the 7 parthenocarpic fruits, and the use of IA and NA at lower concentrations on the ovary, or from 0.05% to 5.0% on the stigma, produced negative results. Similarly, no fruits were induced by using NA as a spray (0.01% and 1.0%) on emasculated flowers, or by using several concentrations of NA and IA in lanolin paste at the base of flower clusters. Crossings and selfiings involved 33 flowers, and resulted in 10 normally-seeded fruits.

On Katahdin potato variety, 207 blossoms were treated, with only 11 seedless fruits resulting. From 31 crossings and selfings 4 normally-seeded fruits were obtained. As on the Earlaine variety, treatments of flowers at the cluster base with lanolin paste, or by spraying, induced no seedless fruits. Applications of paste at concentrations lower than NA 1.0% gave negative results, except where the base of the flower were treated, when 0.1% NA lanolin paste induced 6 very small fruits, all borne on one cluster. These fruits were only one-thirtieth as large as normally-seeded fruits, and only one-tenth as large as the other seedless fruits obtained.

Tomatoes

Results with hormone treatment of 384 flowers of Earliana, V121 and Vetomold tomato varieties were much more positive than those obtained by similar treatments on the closely related potato plants. The treatment of 58 ovaries with NA and IA lanolin paste at concentrations ranging from 0.025% to 5.0% resulted in 39 seedless fruits. Treatment of 87 stigmas with the same range of pastes induced 53 seedless fruits.

The cluster base treatments (NA paste 0.05% to 2.5%) involved 47 unemasculated flowers. Only 5 seedless fruits resulted, but 38 normally-seeded fruits were borne on the treated clusters.

Tomato flowers sprayed with NA concentrations from 0.005% to 0.25% resulted in 97 seedless fruits from 208 treated flowers. These flowers were emasculated a few days before being treated. At least 2 sprays were made, at intervals of 2 days. The higher concentrations gave as many seedless fruits as the lower, but they were smaller and much more warped and injured by the spray, as was also any foliage that was touched by the stronger sprays.

The seedless tomatoes induced by hormone treatments were rather small. In fact, 54% were classed as 1 inch or smaller in equatorial diameter, 22% were between 1 and 2 inches, and 24% were 2 inches or over.

The effective range of plant hormone concentration in inducing seedless tomatoes was very wide, as it was also for petunia. Combined with lanolin to form a paste, the range was from 0.01% to 5.0%, although concentrations of 0.5% to 5.0% injured the fruit and pedicel to varying degrees. Spray concentrations on tomatoes were effective from 0.005% to 0.25%, but again the high concentration (0.1% to 0.25%) caused injury. Severe epinasty occurred on the foliage when the clusters were sprayed with the higher concentrations, and the seedless fruit borne on these clusters was dwarfed and rough.

The majority of the seedless tomatoes contained very small seed initials or (in a few cases) normal-sized empty seed coats. A few had solid-fleshed locules, but in most the locules were filled with soft gelatinous substance.

Apples

In addition to entire trees that were power-sprayed with hormone solutions, 3,293 individual flowers (from 5 varieties) were treated with NA in lanolin paste and hand-sprayed solutions. Most of the treated flowers were emasculated in the pink bud stage, and groups of 2 to 5 clusters of flowers were bagged with brown paper bags. These bags were left on until July 2, full bloom and treatment being on June 8 and 9.

Only 1 seedless fruit was borne on a treated flower, but this was on a variety of *Pyrus malus var. apetala*, and the fruit of this tree is normally seedless. Therefore it is doubtful if the treatment had any effect. Gustafson (5) had slightly better success, for when he treated nearly 1,000 apple bossoms, he obtained 3 lop-sided seedless fruits. Gardner and Marth (1) and Varrelman (7) each report no success in inducing parthenocarpic apples with hormones.

NA spray solutions stronger than 0.05% killed the bagged twigs by Sept. 21, but paste applications, up to 1.0% NA, did not kill back the treated spurs or twigs. In common with clusters treated by spraying, those treated with paste retained their dead blossoms throughout the growing season until early winter. The failure of hormone treated flowers to abscise is a well-known attribute of all the active hormone chemicals.

When entire trees were power-sprayed at full bloom on June 8, no seedless fruits resulted. Concentrations of NA 0.001% killed or incapacitated much of the bloom and a light to very light set of normally-seeded fruit resulted. Higher concentrations (0.005%) rendered the set even lighter or reduced it to zero, and the single tree sprayed with NA 0.01% had no fruit whatever, but the dead blossoms were still adhering late in the autumn. On this tree, too, the foliage showed much more injury than on those sprayed with lower concentrations of NA, but the foliage had recovered completely by the end of the season.

CONCLUSIONS

The main purpose of this trial was to obtain information on the possibilities of using plant hormones to increase the set of apples in seasons when pollination conditions are poor. It was also hoped that seedless apples could be produced, and that these would have a fairly solid core that would be commercially acceptable, as with seedless grapes and navel oranges. In the light of the results on potatoes, petunia and tomatoes, where the seedless fruits produced were smaller than normal and frequently badly distorted in form, and also because it is well known that parthenocarpic apples induced by aphis clusters on the blossoming spurs are small and irregular, it is questionable whether artificially induced seedless apples would be of value commercially. However, experimental results reported here were negative as far as apples are concerned, although results with petunia and tomatoes were positive, and seedless fruits were easily induced.

No experimental work has hitherto been reported on parthenocarpy in potatoes, but in view of the close botanical relationship between potato and tomato plants, it is somewhat surprising that so little effect was secured by hormone treatment of potato blossoms, whereas the induction of parthenocarpic tomatoes presented no difficulty. The physiological or genetic incompatibility usually found in attempts to obtain seed balls by crossing or selfing commercial potato varieties may have a bearing on this result.

It is possible that new hormone substances, such as naphthoxyacetic acid, might be effective as parthenocarpy inductors on tree fruits, where naphthaleneacetic acid has failed.

SUMMARY

Parthenocarpic (seedless) fruits were easily induced artificially with plant hormone chemicals on petunia and tomato flowers. On potato flowers the results were not so effective, and on over 3,000 apple blossoms the treatments produced negative results. Concentrations of naphthaleneacetic acid and indolebutyric acid were found to be effective over a wide range on tomato and petunia flowers. For naphthaleneacetic acid this range for lanolin paste was 0.01% to 5.0% and for spray solutions, 0.005% to 0.25%.

In an attempt to induce a set of seedless apples in a season when conditions were unsatisfactory for natural pollination, it was concluded that the use of naphthaleneacetic acid is completely ineffective.

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A STUDY OF THE CODLING MOTH AND ITS PARASITES IN CALIFORNIA

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Codling moth control has, for some years, been recognized as a problem of increasing difficulty in all parts of North America. As part of a program of control, the Division of Entomology of the Dominion Department of Agriculture, working through the Dominion Parasite Laboratory at Belleville, has introduced into Canada from France, two parasites which were found during investigations conducted on the biological control of this insect in Southern France in 1939 and 1940. In the 1941 season, a survey for parasites of the codling moth was made in California, since reference to literature suggested that this area might be expected to provide a richer fauna than any other section of North America, and would probably show also an exceptionally high degree of control of an introduced pest by native parasites and predators. Some data collected during this survey are given in this report.

SEASONAL HISTORY AND STATUS OF CODLING MOTH IN CALIFORNIA

First established in California on apples and pears about 1872 (Essig, 12), the codling moth has become since 1918, the major pest of walnuts, and in 1929 was recorded as maintaining itself in parts of S. California on other stone fruits such as plums, apricots and cherries independently of its usual hosts (Smith, 25). There has been much discussion of, and some work done on the question of the relation of the apple infesting codling moth to the so-called "walnut codling moth." It is known that in parts of California the species has been a severe pest of apples and pears since 1880, whereas walnuts in the same districts did not suffer infestations until 1931 (Boyce, 5). It appears probable that there is a "host-determined" race on walnuts, but it has not been proved that it is a distinct genetic race (Smith, 24).

Generally speaking, there are two well defined broods (of moths?) throughout the state, while a partial third is not uncommon in some of the warmer areas. However, demarcation of the latter broods is very difficult because of overlapping. Emergence of moths from the hibernating material commences about mid April and continues through May and June, with the main peak of emergence usually in the latter part of May. Delimitation of the end of the second brood is difficult but is regarded as falling in the last half of August. In the coastal regions there is often low uninterrupted emergence through July, August and September. A small percentage of the mature worms spinning up during the earlier summer months remain in this stage until the following spring.

The codling moth problem, though serious, is probably not yet as serious a problem in California as it is in some other sections of North America. Dr. Macleod (19), of the University of California, Berkeley, has

[1] Junior Entomologist.

stated that the general trend of codling moth populations in Californian orchards is upward, with all indications suggesting that eventually the position will be similar to those parts of the country where from 6 to 12 cover sprays are necessary for fruit protection. At present control methods consist mainly of insecticidal programs which vary with the type of host, though there is some recognition of the importance of sanitary practices. For apples and pears the general practice is to follow the University recommendation of a calyx spray of 4 lb. of standard lead arsenate when 50 to 70% of the petals are off, followed by a second calyx spray within 10 days from the start of the first. All subsequent sprayings, frequently 4 or 5, and in some areas such as Yucaipa 7 or 8, are timed by the bait pan method devised by Borden (4), and these applications are made within a 10-day limit from the beginning of each major peak of emergence. However, the writer has talked to some growers who maintain an arbitrary fortnightly spray program throughout the season, while other growers, usually supply-the local markets and cider industries, bear the losses and have no spray or other control practices.

With walnuts, the other major host of codling moth in California, one thorough properly timed spray of basic lead arsenate generally gives satisfactory control for the season—a somewhat striking contrast to the position with apples. Recently, the increasing importance of the pest all over the state has led to experiments by the University with two treatments in a season. Infestations on other stone fruit hosts of the moth are usually treated with one or two spray applications.

INVESTIGATIONS

Areas Investigated for Parasites

The apple, pear, and walnut growing areas of the state of California cover a wide range of ecological conditions, and the selection of districts for the study of parasites was determined by four main considerations. Firstly, there was the occurrence of the three broad climatic zones into which the state is divided by horticulturists. These three belts are the Coastal, Valley and Mountain, with the so-called Foothill zone considered as a modification of the Valley type of climate. These general divisions are endorsed by Bowie (Climatic Summary of the United States, Section 16, U.S.D.A. Weather Bureau, 1934,) who points out that the terms "southern," "northern" etc., do not apply to the various sections of California because of such factors as the north-south deflection of the isotherms: and he agrees that a more appropriate classification of the climate is that adopted by horticulturists.

The second consideration in the selection of sampling localities was the distribution in the state of the chief host plants of the codling moth, namely, apple and walnut. Reference to an outline map of California showing the apple acreage by counties, indicated that two-thirds of the total acreage is in the northern coastal counties of Sonoma, Santa Cruz, and Monterey, the remaining third being scattered throughout the Central Valley, foothills and mountains. No maps on the walnut acreage are available, but figures in the annual reports of the California Walnut Growers' Association show that this is concentrated in Southern California,

particularly in the coastal counties of Ventura and Los Angeles. In recent years, however, Valley counties such as San Joaquin have attained crop productions second only to those of Ventura County. There is, of course, only a very limited cultivation of walnuts at the higher altitudes in the mountains.

Thirdly, there was the question of the availability, within these major and minor host plant areas, of orchards which had received little or no insecticidal treatments for codling moth for periods of at least two years preceding the 1941 season. This choice of untreated orchards was considered desirable on general principles as being likely to give conditions more favourable for the activities of any native parasites and predators.

Fourthly, published records of parasites and predators of codling moth in California gave some indication of their distribution in the state.

A fifth, and important non-biological consideration was the amount of money available for covering the labour and travelling expenses over the widely separated parts of the state.

On the basis of the above points the districts shown on page 460 were selected for investigation, and the location of the sampling stations and the apple and walnut areas are shown in a general map of California (Figure I).

Attention was concentrated on the larval and pupal parasites and predators of the codling moth as it was not practicable to make a study of the egg parasites in the various sections owing to the large amount of time involved in locating reasonable numbers of host eggs. Records of parasitism and predatism were obtained chiefly by examination of burlap bands, which were placed either one per tree near the ground level, or one per main branch above the crotch. These bands were made from burlap strips one foot wide, folded 4 thicknesses to form a 3-inch band in order to ensure the exclusion of light. This trapping of mature larvae was supplemented in some orchards by collections of worms by the scraping of bark and the opening of apples, etc. There are, of course, some obvious drawbacks in this banding technique: the heavy mortality of the larvae when they are forced to spin a second cocoon in corrugated paper strips, and the probable inaccessibility of a large percentage of the larvae to attack by any parasites, are the more important of these. There is the further possibility that the concentration of the hosts within these bands provides unusually favourable conditions for the predators so that the value of the latter receives disproportionate emphasis. For example, the writer has found as many as 30 Raphidiid larvae working in one band in orchards in the foothills at Auburn, and it is unlikely that the resulting wholesale destruction of codling moth larvae is at all representative of the position in the orchards.

Larval and Pupal Parasitism in the 1941–42 Season.

An indication of the extent of the parasitism of the codling moth larvae and pupae throughout the state can be obtained by an examination of Tables 1, 2, and 3. These data refer only to host material collected from tree bands, and at the time of the summer collection about 33% of the larvae had pupated. It was only possible to make a few observations

on the overwintering larvae of the 1940–41 winter, the data being secured by the co-operation of growers who had banded their trees as part of a control program. The orchard at Little Rock had been sprayed annually for many years and observations in the district were not continued because of failure to locate a suitable unsprayed plot. The town lies on the west edge of the Mojave Desert at an elevation of approximately 3,000 ft. above sea level and has a climate characterized by high summer temperatures.

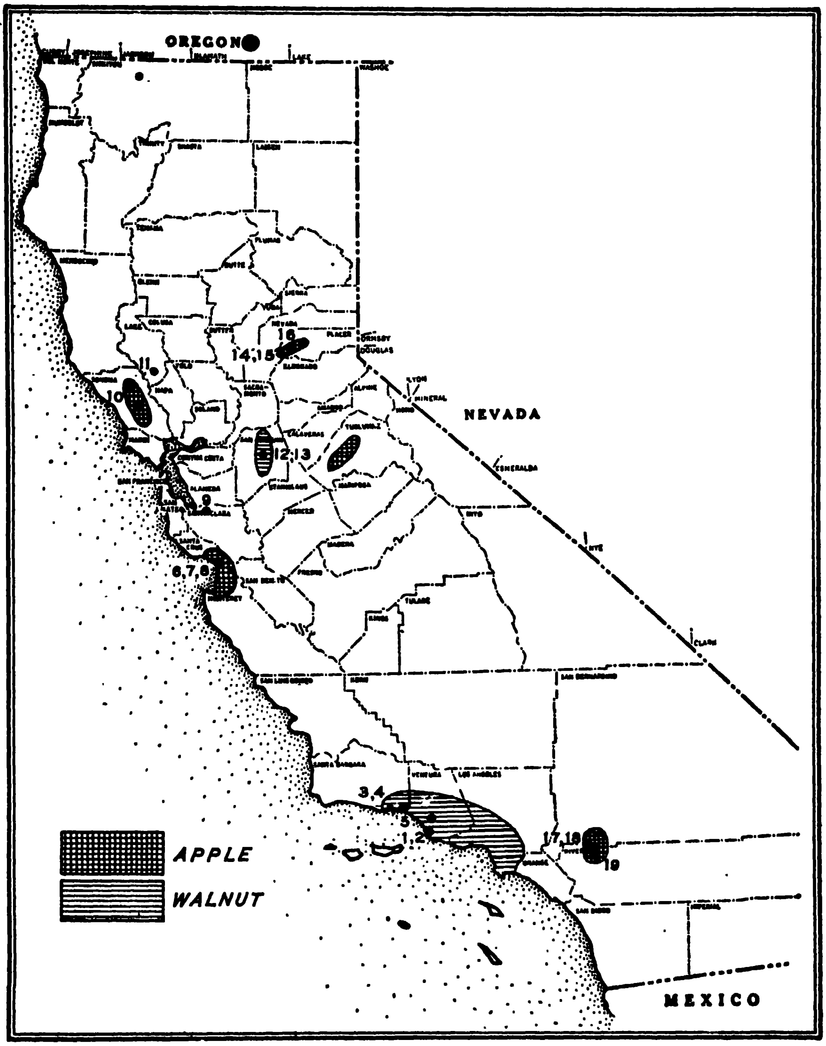

FIGURE 1. Map of the State of California, U.S.A., showing the location of sampling stations and the apple and walnut areas.

All the species listed in the tables were primary, but *Dibrachys cavus* Walk. also developed as a secondary on *Ascogaster quadridentatus* Wesm. = (*carpocapsae* Vier.). The figures for the external and internal parasitism of the summer generation are based on an examination of, and emergence

LOCATION OF SAMPLING STATIONS

Climatic Zone	District	Elevation	Orchard	Previous spray treatment	No. of trees banded exmnd.
Coastal	Saticoy	150 ft.	(1) Walnut. Lloyd.	Annual spray	100
			(2) Walnut. Saticoy citrus	Annual spray	100
	Carpinteria	40 ft.	(3) Walnut. Edwards.	Annual spray	100
			(4) Walnut. General ass.	None for years	30
	Kasitas	1,000 ft.	(5) Apple. Anderson	None for 10 yrs.	24
	Watsonville	30–70 ft.	(6) Apple. Brock.	None for 2 years	100
			(7) Apple. Hill	None for years	100
			(8) Apple. Earle	Annual until 1941	100
	San José	30 ft.	(9) Apple. ?	None until 1941	24
	Graton	190 ft.	(10) Apple. Olman	None for 2 years	50
	Lower Lake	1,300 ft.	(11) Apple. Willson	None for years	20
Valley	Linden	40 ft.	(12) Walnut. Meier	None for years	24
			(13) Walnut. Carroll	None until 1941	40
Foothills	Auburn	1,200 ft.	(14) Pear. Crockett	None for years	30
		1,800 ft.	(15) Apple. Simpson	None for years	60
	Colefax	2,500 ft.	(16) Apple. Rolph	None for 2 years	40
Mountain		3,000 ft.	(17) Apple. Webster	None for 10 yrs.	100
		3,500 ft.	(18) Apple. Parrish	None for 3 yrs.	70
	Arrowhead	5,000 ft.	(19) Apple. Davis	None for years	40

from, all hosts collected. With the hibernating material, the external parasitism is based on the total sample collected and that of the internal parasitism on the emergence of adults in the following spring. There was a heavy mortality in the overwintering larvae but this is apparently usual for the host and due in part to the disturbance of the winter cocoons.

Not represented in the tables are supplementary collections of worms from host fruits, etc. in some of the orchards. These gave the following results, largely substantiating those of the band examinations.

TABLE 1.—PARASITISM OF OVERWINTERING CODLING MOTH LARVAE 1940–41

District	Orchard	Size of sample	Total emergence from sample	*Ascogaster carpocapsae*	*Aenoplex carpocapsae*	*Aenoplex betulaecolae*	*Lixophaga orbitalis*	*Achaetopsis tortricis*	Total external parasitism	Total internal parasitism
1. Carpinteria	Walnut	397	189 (47%)	–	5	–	8	1	1.2%	4.7%
2. Watsonville	Apple	667	452 (68%)	97	12	3	–	–	2.2%	21.2%
3. Little Rock	Pear	717	276*(39%)	–	8	–	–	–	1.1%	0
		1781	917 (52%)	97	25	3	8	1	1.5%	11.5%

* Cocoons taken from naphthol treated bands.

Summer brood larvae:

(*a*) 1½ tons of wormy, blighty walnuts, collected in late June and early July from two orchards in the Saticoy area, were placed in a large room in the Citrus Experiment Station. The only emergents were thousands of moths.

(*b*) 400 wormy nuts, collected August 10th, from a third grove in Saticoy showed no parasitism though the walnuts selected were those with good exposures of the burrows for the action of any parasites such as *Calliephialtes nucicola* Cushm.

(*c*) In early July a sample of 100 wormy apples at Kasitas Pass had 4% of the codling moth larvae parasitized by *Lixophaga orbitalis* Aldr.

(*d*) In early August 250 wormy apples from Lower Lake had 7 of the host larvae parasitized by *Macrocentrus ancylivorus* Rohw.

(*e*) A sample of 200 wormy apples from Yucaipa (Webster) had all the summer brood hosts unparasitized.

(*f*) 10 to 12 acres of apple trees in 5 orchards in the Watsonville area were banded with corrugated paper in the summer of 1941 and the bands with summer brood larvae were sent down to Riverside for mass emergence in the insectaries. Parasite emergence was very small and the specimens recovered were the same species as those noted in the detailed examinations.

Table 2.—Parasitism of firstbrood summer larvae in California (July 1941)

Orchard	Sample	*Ascogaster carpocapsae*	*Aenoplex carpocapsae*	*Aenoplex betulaecola*	*Lixophaga orbitalis*	*Anachaetopsis tortricis*	*Ephialtes sanguineipes*	*Ischnus* n. sp.	*Macrocentrus ancylivorus*	*Dibrachys cavus*	Total external parasitism	Total internal parasitism
1	160	–	–	–	–	–	–	–	–	1	0.5%	0
2	150	–	–	–	–	–	–	–	–	1	0.6%	0
3	100	–	–	–	3	–	–	–	–	2	2.0%	3.0%
4	None											
5	80	–	–	–	10	–	–	1	–	–	0	13%
6	150	28	–	–	–	–	–	–	–	3	2.0%	17%
7	50	1	–	–	–	–	–	–	–	–	0	2.0%
8	300	22	7	2	–	–	1	–	–	4	4.3%	8.6%
9	200	11	–	–	23	–	–	–	–	2	1.0%	17%
10	500	78	–	–	6	–	–	–	–	–	0	16.8%
11	250	1	–	–	–	–	–	–	8	–	0*	3.6%
12	None											
13	150	–	–	–	21	–	–	–	–	–	0	14%
14	250	–	–	–	6	–	–	–	–	–	0	2.4%
15	400	–	–	–	6	–	–	–	–	–	0	1.5%
16	250	–	–	–	7	–	–	–	–	–	0	2.8%
17	402	–	1	–	3	–	2	–	–	–	0.7%	0.7%
18	461	1	–	–	1	–	–	3	–	–	0.2%	0.9%
19	86	–	–	–	–	–	–	–	–	–	0	0
Totals	3939	142(3.5%)	8(0.2%)	2	86(2.2%)	0	3	4	8	13	0.6%	6.3%

Table 3.—Parasitism* of overwintering larvae (1941–42) in California (Nov. 1941)

Orchard	Sample	Total emergenee from sample	*Ascogaster carpocapsae*	*Aenoplex carpocapsae*	*Aenoplex betulaecola*	*Lixophaga orbitalis*	*Anachaetopsis tortricis*	*Ephialtes sanguineipes*	*Ischnus* n. sp.	*Macrocentrus ancylivorus*	*Dibrachys cavus*	Total external parasitism	Total internal parasitism
1	200	122(61%)	–	1	–	1	–	–	–	–	–	0.5%	0.8%
2	412	203(51%)	–	12	–	–	–	–	–	–	–	2.9%	0
3	400	220(55%)	–	6	–	4	–	–	–	–	–	1.5%	1.8%
4	155	108(60%)	–	24	–	3	–	–	–	–	–	9.4%	2.7%
5	188	87(46%)	–	1	–	1	–	–	–	–	–	0.5%	0.8%
6	1805	902(50%)	142	–	–	–	–	–	–	–	–	0	15.5%
7	392	199(51%)	2	11	–	–	–	–	–	–	–	2.8%	1.0%
8	3080	1600(52%)	152	7	–	1	–	–	–	–	–	0.2%	9.5%
9	604	225(42%)	12	–	1	15	2	–	–	–	–	0.1%	11.4%
10	904	514(57%)	122	–	–	–	–	–	–	–	–	0	23.7%
11	314	258(82%)	1	2	2	–	–	–	–	1	–	1.3%	0.7%
12	156	86(55%)	–	–	–	6	–	–	–	–	–	0	7.0%
13	1240	730(58%)	–	–	–	29	–	–	–	1	–	0	4.1%
14	43	31(72%)	–	–	–	–	–	–	–	–	–	0	0
15	482	309(64%)	–	–	–	3	–	–	–	–	–	0	1.0%
16	744	434(58%)	–	1	–	18	–	–	1	–	–	0.1%	4.2%
17	1902	1243(65%)	14	6	–	–	–	2	–	–	–	0.3%	0.8%
18	2542	1552(60%)	9	3	–	6	–	–	–	–	–	0.1%	1.0%
19	679	471(69%)	–	5	–	–	–	–	–	–	–	0.7%	0
Totals	16242	9294(57%)	454(4.8%)	79(0.9%)	3	87(0.9%)	2	2	1	2	0	0.9%	5.8%

Winter brood larvae:

(a) In late September 1941, 1,100 affected walnuts at a Linden grove were opened for worms and 160 found. No parasites were seen.

(b) In May 1941, a thorough examination was made of moth emergence cages containing an estimated 15,000 overwintering larvae in bands which had been obtained for Dr. Boyce of the Citrus Experiment Station by the Puente Walnut Growers' Association (S. California, near Los Angeles). No parasites were found although no external parasites were expected in view of the method of collection.

(c) Several thousand of the 1941–42 hibernating larvae from bands in the Yucaipa and Watsonville areas were given to Dr. Boyce of the C. E. S. for experiments on the walnut and apple race question. A cursory examination of this material was made, and there is no reason to believe that the parasitism differed from that of the samples taken from the same orchards and shown in the table.

(d) Between January and March 1942, collections of at least 25,000 overwintering larvae were obtained from numerous walnut groves under the Saticoy Walnut Growers' Association. With the generous co-operation of Mr. Barrett, entomologist to the Association, large numbers of worms and cocoons being removed from the bands by the team of workers employed by the Association were thrown into tins containing corrugated paper rolls. The material was then forwarded to Belleville; emergence details are not yet available.

It is apparent from inspection of the tables and the above data that the overall controlling effect of the native larval and pupal parasites in the state as a whole is very small. The only species of *any* consequence are *Ascogaster quadridentatus*, *Aenoplex carpocapsae* Cushm. and *Lixophaga orbitalis*. *Ascogaster* was the predominant species in the summer and winter, and is, of course, an introduction on the West coast. Even this species was of sporadic distribution and somewhat low incidence showing a 3.5% parasitism of the summer brood larvae and 4.8% of the overwintering brood. This figure of 4.8% parasitism by *Ascogaster* is undoubtedly much lower than the actual since there was a very heavy mortality of the hosts containing *Ascogaster* larvae. Thus in the areas where *Ascogaster* was observed some 11,543 hibernating codling moth larvae were collected, and examination revealed that 2,593 (22.4%) of these were of the very small size characteristic of those parasitised by this species. The numbers of such small larvae in any collection is a reasonably reliable guide for the parasitism by *Ascogaster*, and on this basis, 41.7% of the Watsonville material and 33.5% of the Graton material, were parasitised by this species.

Summer records show that the species was confined to the coastal zones of Watsonville, San José, Graton and Lower Lake, while the larger winter samples indicated its presence in the Mountain zone of Yucaipa; it was not obtained in the hot Central Valley and the Foothills. It is also interesting to note that it was taken only in the apple orchards though it has been liberated in walnut districts such as Saticoy.

Even with the lower parasitism figures for *Ascogaster*, the figures for the most prevalent native western parasites, *Aenoplex carpocapsae* and *Lixophaga orbitalis*, do not compare too favourably. The Tachinid was present in all climatic zones in apple and walnut orchards, and effected a summer parasitism of 2.2% and winter parasitism of 0.9% for the state. There were several orchards where the summer collections showed up to 14% parasitism by the species, but it may well be that these early summer brood hosts were more heavily parasitised than the later (that is, the small samples probably were not representative of the conditions). *Aenoplex carpocapsae*, the solitary external Ichneumonid parasite on spun-up larvae, appeared of no consequence in the summer brood and its incidence in the collections at this time was easily exceeded in the small winter samples of April 1941. The species was more abundant in the autumn of 1941, and there was a parasitism of 0.9% for the state in early November. This figure may be a little on the low side as it is known that *Aenoplex* is active in some regions in late autumn and early winter. Apart from one specimen from the orchard at an elevation of 2,500 ft. in the Foothills, this species, like *Ascogaster*, was not recovered in the Central Valley and Foothills, but did occur in walnut groves.

The remainder of the native species obtained in the survey seem to be casual parasites of the codling moth. The *Macrocentrus ancylivorus* has been introduced into Washington and Oregon, and has spread into the extreme north of California.

No important differences in the native parasite fauna of the codling moth in regard to host plants and climatic zones were revealed by the survey. Minor differences have been noted in the preceding paragraphs.

Predators

No quantitative work on the predators of the codling moth larvae and pupae was attempted. The larvae of *Cymatodera ovipennis* Lec. and *Cymatodera* sp. (Coleoptera, Cleridae) were active in the bands throughout the winter; and *Hydnocera scabra* Lec. (Coleoptera, Cleridae) was noted in several walnut orchards and in some of the apple orchards in the Foothills. A Raphidiid larva, which the United States Natural Museum was unable to identify, was general throughout the area sampled. Unsuccessful attempts were made to rear this latter species through to the adult stage.

The destruction in the bands of spun-up codling moth larvae and pupae by this Raphidiid and the *Cymatodera* spp. was impressive in some orchards, but it has been pointed out previously that the concentration of hosts within the bands may have given an exaggerated importance to this mortality factor. However, on the basis of somewhat cursory visual inspections and without making exact counts, it was evident that the above predators of the codling moth were frequently producing a heavier mortality than that caused by the larval and pupal parasites in the bands.

Notes on the parasites

(i) *Aenoplex carpocapsae* Cushm.

Apparently this species, and occasionally a few other members of the same genus, are the only solitary external parasites attacking the codling moth larvae within the cocoon in California. The number of generations

in the season is not well defined, but in most districts there are at least two. Adult parasites emerge from the overwintering cocoons several weeks before peak emergences of the moths, and deposit their eggs on some of the more retarded codling moth larvae in the winter cocoons, and later, on the first summer brood larvae. Throughout the months of July and August, and early September, the majority of these specimens go into a diapause as mature larvae in the cocoons. This diapause occurred also in some laboratory experiments in the early summer of 1941. The small numbers of this species which were found in the field in the summer of 1941 suggest, however, that the parasite may also utilize an alternate host (or hosts) between the spring and September, in which month the larvae transform. The resulting females actively attack the fresh hibernating *Carpocapsa* larvae. Development of the parasite larvae in these hosts proceeds slowly, and while a proportion of them probably transform and start a partial third generation, the majority remain as mature larvae throughout the winter. There is no rigid diapause, however, since the species has been seen by the writer in first, second, and fourth larval, pupal, and adult stages, in various walnut orchards in the coastal county of Ventura in January, one of the coldest months in California; while in March the species was seen as early larvae and as mature larvae in cocoons in an apple orchard at Yucaipa, which has an elevation of 3,500 feet above sea level.

It appears quite definite from the results of the present survey that this parasite is most active on codling moth during the autumn and winter months and this confirms previous observations. Flanders (15) remarked that the *Aenoplex* spp. in the Ventura area attacked the hibernating larvae and were most active during October and November; and Strong (26) states that studies of the cocoon parasite *Aenoplex carpocapsae* showed that breeding nearly ceases during July and August but becomes normal again in September. After being quite abundant in certain orchards in southeastern Illinois in 1935, this species virtually disappeared from the same orchards in 1936.

In the course of laboratory experiments on host selection, a few observations were made on the biology of the parasite. Mating occurs very soon after the emergence from the cocoon, and lasts for 30 seconds or less. Copulation of the sexes seems to be more easily effected by confining 3 or 4 day old males with freshly emerged females in small vials. Males are able to copulate several times in life. Oviposition commences the day after mating so that the pre-oviposition period is probably between 12 and 24 hours. The codling moth larva is first paralyzed and the egg is deposited on any part of the host, or occasionally at any point within the cocoon. Females were never seen to paralyze or oviposit on codling moth pupae. Oviposition by the parasite was better when the females were supplied with the normal cocoons (either scattered loosely on the floor of the cages or gummed on strips of stiff paper) rather than with the conventional bands containing spun-up larvae. It was noticed that the females had some difficulty in locating the hosts when these were not actually in the surface grooves of the corrugated paper with the cocoon fully exposed to the actions of the parasite. This point is of practical interest since it was noticed in field examination of the burlap bands that the larvae parasitized by

this species were frequently those near the edges of the bands. It is quite possible that the majority of the host larvae in the bands and under the bark are inaccessible to the females.

At 75° F. oviposition continued daily until 3 or 4 days before death, which occurred on the average 30 days after emergence from the cocoons. No exact counts of the numbers of eggs deposited by individual females were made, and females were simply noted as laying up to 10 eggs during the first week of life, and later 3 or 4 per day. It is estimated that a female probably parasitized at least 80 hosts during life, and there was an appreciable amount of superparasitism. On rare occasions two specimens developed on one host.

The egg hatches within 48 hours at 75° F., the larvae immediately starting external feeding. Within another 6 or 7 days four larval moults take place, the cocoon is spun within the codling moth cocoon, and the larval meconium is cast. The pupal stage lasts 10 days so that the entire cycle takes about 18 days at this temperature. Males have been obtained within as short a time as 13 days; this sex usually appears a few days before the female.

McClure (20) has published some notes on two types of life cycles with the male of this species. A small larval type only partially devoured the hosts, went through a relatively brief resting period of 1 to 7 days, and then transformed; a large larval type, which completely devoured the host except for the head capsule and a piece of dried skin, went into a prolonged resting stage of from 37 to 63 days. Reared under controlled conditions, 13% of the progeny had long cycles, 47% short cycles, and 40% died. This variation has not been observed during the maintenance of small laboratory stocks of this species in California in the winter and spring months of 1941–42. The same author states that the breaking open of the codling moth cocoon and exposure of the parasite cocoon to light, results in the latter's colour changing from white, through yellow, to black. Parasites bred at the Riverside insectaries have all spun cocoons which remained white even when freely exposed to air and light in small open vials. Cocoons of white, brown, etc., hues are, however, common in the field (Flanders, 15).

(ii) *Aenoplex betulaecola* Ashm.

This species has recently been recognized by Cushman (135) as synonymous with *A. plesiotypus* Cush., also recorded from Codling Moth (Cushman, 8). The few specimens obtained in the present survey were solitary, and it may be assumed that the general biology is similar to that of *A. carpocapsae.*

(iii) *Lixophaga orbitalis* Aldr.

A few details of the seasonal history of this species are available. First brood summer larvae are parasitized by the *Lixophaga* females which emerge from the overwintering codling moth larvae. An unknown number of generations may intervene between this time and late September, when the Tachinid is found as a first or second instar larva inside the hibernating host larva. This species remains in this stage until the following April and May,

when development is resumed. The mature maggot soon emerges from the *Cydia* caterpillar, and the puparium is formed inside the cocoon of the host. Emergence of the adults occurs in about 15 days' time. Appreciable mortality in the puparia within the host cocoons was recorded in the overwintering material of 1941–42.

Attempts to rear this species in the laboratory were not successful because of failure to secure mating. No obvious reason can be advanced for this lack of interest by the males. The sexes, usually with a preponderance of males, were confined in vials and cages of various sizes (cages from 4″ by 5″ by 9″ to 3′ by 3′ by 3′) supplied with food, water and wormy apples and kept in several temperature and light conditions at different hours of the day. At intervals, some of the females were dissected but no eggs had descended into the uterus though the extensive tracheation and structure of this organ indicated that prolonged incubation of the eggs is needed.

Townsend (28) claims that *L. orbitalis* Aldr. and two other species should be placed under the genus *Prolixophaga* pending the erection of a new genus for the three species, and states (27) that *Prolixophaga* parasitizes codling moth, peach moth and similar boring caterpillars, the females larvipositing at the entrance to the burrows. A similar reproductive habit is recorded for *Lixophaga* and *Euzenilliopsis*, and in this latter genus Townsend has apparently included the common larvipositing Tachinid of the sugar cane borer (*Lixophaga diatraeae* Tns., (Scaramuzza, 22)). Californian records of *L. variabilis* Coq. are put under *L. orbitalis* by Aldrich (1), but Townsend (27) maintains that rearing records of *Lixophaga* by both Coquillet and Aldrich have been greatly confused, and that those under *variabilis* bred from *Carpocapsa* were quite certainly *Prolixophaga.* Dr. Reinhard of Texas informs the writer that the species *L. orbitalis* Aldr. is known only from California.

Ignoring this systematic confusion, and judging by the reproductive system and large membranous type of egg of the Californian species, it is probable that the female deposits larvae, or larvae in choria, on the surface of the fruit.

(iv) *Ischnus* n.sp.

Three females reared from codling moth pupae in the summer of 1941 were supplied with larvae, prepupae, and pupae in cocoons. All females took an active interest in the hosts, extensively stabbing some of the pupae. However, only one female deposited eggs. These were placed externally on pupae, but although some of these were transferred to coddled larvae and treated in the same way as in the rearing of *Aenoplex* larvae, all specimens died. Eggs left on the pupae hatched normally but the larvae were unable to survive beyond the first instar, being apparently unable to obtain sufficient nourishment on the strongly chitinized hosts. The external oviposition on pupae is rather puzzling since when collected in the field the cocoons of the parasites were spun within the burst skins of the codling moth pupae. This suggests that the species is either an internal parasite or an external parasite which effects entry into the host at some period of its larval life. Nothing is known of its seasonal history.

(v) *Other Species*

Of the remaining parasite species collected, the only information obtained is that of their status. The Tachinid *Anachaetopsis tortricis* Coq. attacked the larvae, the Ichneumonid *Ephialtes sanguiniepes* Cress. was an internal parasite of spun-up larvae, the Braconid *Macrocentrus ancylivorus* Rohw. parasitized the early larval instars in the host fruit, and the Chalcid *Dibrachys cavus* was a gregarious external on spun-up larvae in the summer brood.

SOME PREVIOUS RECORDS OF CODLING MOTH PARASITES AND PREDATORS IN EASTERN AND WESTERN STATES

For purposes of comparison it is thought useful to include the results of the more detailed investigations on the natural control of the codling moth in North America within the last thirty years.

In 1911–13 Brooks and Blakeslee (7) studied the codling moth in the Central Appalachian region. The work was done by banding 10 to 15 medium sized unsprayed apple trees in ten localities in Virginia, West Virginia, and Maryland, and during the investigation approximately 20,000 larvae were taken from the bands. The authors made no general statement on the importance of natural enemies, and simply recorded that the total parasitism (larval) for all points in 1912 was 0.36% and in 1913, 1.55%. Six Hymenopterous parasites were listed, namely, *Ascogaster quadridentatus* Wesm., *Itoplectis marginatus* Prov., *Macrocentrus* sp., *Meteorus* sp., *Microdus* (*Bassus*) n.sp. and *Phanerotoma tibialis* Hald. The *Ascogaster* outnumbered all other species. A few specimens of (*Hypostena*) *Tachinophyto variabilis* Coq. were also obtained from the larvae. Among the more important predators noted were the ants, *Solenopsis molesta* Say, and *Lasius niger* L. var. *americana* Emery, and the larvae and adults of the beetle *Tenebroides corticalis* Melsh.

More recent studies in Northern Georgia are those of Webb (30) who claimed that "a combination of several native larval parasites form a very important factor in controlling codling moth in N. Georgia." while Webb and Alden (31) stated that 2,593 emergences from 1st, 2nd and 3rd brood larvae during the period 1936–39, 19.1% were parasites. *Ascogaster quadridentatus* and the secondary *Perilampus* sp. constituted 95% of the total parasite figure, with *Pristomerus agilis* Cresson, *Phanerotoma tibialis* Hald. and *Calliephialtes grapholithae* Cress. all considered "of minor importance." By a somewhat unusual arithmetical process, and presumably allowing for the mass field liberations of *Trichogramma minutum*, these authors concluded that the parasites of "the egg and larvae of the codling moth destroy 64.6% of its population." This somewhat high opinion of the controlling effect of parasites in Georgia is endorsed by Webster (32).

Annand (2) reported that work over several years on a mechanical-biological control program for codling moth in West Virginia did not permit of accurate determination of the value of the various natural control factors, though parasite populations remained consistently low while the predators, particularly ants, were more numerous in the untreated orchards.

This author concluded that under certain conditions such a control program gives the grower returns comparable to those obtained with routine spray applications. Unfortunately, no detailed figures of the parasitism of the host during this experiment are available in the published report, but it may reasonably be inferred that the position showed no very significant difference from that noted by Brooks and Blakeslee above.

Boyce (6) observed a variety of parasites and predators in the Niagara district of Ontario in 1937–40, but these were not sufficient for economic control of the host in the sprayed and unsprayed orchards investigated.

In the West a fairly extensive examination of the codling moth problem was made in the Grand Valley of Colorado in 1915–16 by Siegler and Plank (23). *Tenebroides corticalis* Melsh. and a spider *Coriarachne versicolor* Keys were recorded as predators, and *Trichogramma minutum* Riley, *Dibrachys clisiocampae* Fitch, and *Arthrolytus apatelae* Ashm. as parasites. The workers considered that these enemies played a very unimportant part in checking the moth in the area under investigation.

In New Mexico orchards, Garcia (17) reported that the only parasite obtained from bands was *Dibrachys boucheanus* Ratz., and that the coleopterous predator *Cymatodera aethiops* Wolcott continued to be the most evident enemy. Doten (10) investigated the Hymenopterous parasites of *C. pomonella* in Nevada from 1910 to 1915 and recorded *Aenoplex* sp. nov., *Pimpla* sp. nov., and *Meraporus* sp. nov., the latter a gregarious internal Chalcid in the host pupae. No indication was given of the extent of the attack by these species, but in 1915, the author stated that there was little indication that they would ever be of any great importance in checking the codling moth. *Secodella acrobasidis* Craw. was observed as an external parasite of *C. pomonella* larvae within the host fruit at Mesa, Idaho, by Wakeland (29) but although the host infestations were noticeably mild in that district, Wakeland saw no reason to believe that the parasite was of primary importance in that connection. Yothers, Allen and Scheffer (33) found a high percentage of parasitism (in July and August, 80–84%) of codling moth eggs by *Trichogramma minutum* in Wenatchee, Washington. Parasitism was noted throughout north central Washington, and as a rule higher in unsprayed or poorly cared for orchards, while little or no parasitism was noted in well-cared for orchards.

In California, no extensive study of the natural enemies of codling moth in apples appears to have been made. Hensill (18) obtained the parasites *Lixophaga variabilis* Coq. and *Ascogaster quadridentatus* from several thousand larvae collected from bands in the Santa Clara Valley. Parasitism by the former was up to 5% in some lots, but only a few specimens of the latter were taken.

With walnuts, Quayle (21) mentioned *Trichogramma minutum*, *Aenoplex carpocapsae*, and Carabid and Clerid beetle larvae, but he considered that seldom, if ever, were the enemies of codling moth important enough in themselves to exercise satisfactory control. Likewise, Boyce (5) in a later paper on codling moth in Persian walnuts, generalized to the effect that "natural enemies do not ordinarily exert a sufficient effect upon the codling moth population in walnuts to warrant consideration in the control programme."

Flanders (15) summarized the findings of four years' observations on Cydia parasites and predators in the vicinity of Saticoy, Ventura County. The following species are given: *Aenoplex carpocapsae* Cushm., *A. plesiotypus* Cushm., *Aenoplex* n.sp., *Ephialtes sanguiniepes* Cress., *Exetastes* n.sp, *Trichogramma* sp., *Prospaltella* sp., and *Lixophaga* n. sp., as parasites and *Cymatodera angustata* Spin., *C. ovipennis* Lec., and *Hydnocera scabra* Lec. as predators. The most prominent checks were the *Aenoplex* spp., and *Trichogramma* spp. It was estimated by this author that 50% of the host eggs deposited in May and June were parasitized by the latter, while regarding *Aenoplex*, it is recorded that: "At Carpinteria 20% of 800 larvae found in bands on the walnut trees were parasitized. On Oct. 24, 1925, the band on a large crabapple tree at Saticoy contained 32 larvae; of these 22 were parasitized." However, in an earlier paper in 1926, Flanders (14) adds that in the neighbourhood of this latter tree, 32 of the 417 *Cydia* larvae collected were parasitized, so that the parasitism of the one tree was exceptional. Other figures for parasitism were published in 1926, when 24 specimens of *Lixophaga* emerged from 300 overwintering larvae, and in 1929, (16) where it is stated that on Sept. 1, 1928, a random sample of 50 immature larvae from a walnut orchard where *Calliephialtes* n. sp. has been observed, gave 15 parasitized, that is a 30% parasitism. Some notes on this latter larval parasite—*Calliephialtes nucicola* Cushm.— are given by Barrett (3), who claimed that it was quite common in some walnut orchards of Ventura County in the summer of 1929, and 141 specimens were reared between Aug. 17 and Sept. 20th from infested walnuts. (In the summer of 1941, Mr. Barrett informed the writer that this emergence was from 5 to 6 tons of blighty, wormy nuts so that the descriptions of the parasite's incidence as "quite common" is misleading.)

The foregoing review of the more important published data on codling moth parasites and predators in N. America indicates that most workers regard these enemies as of little controlling value. In certain sections investigations of rather limited nature have suggested that they play a significant rôle, and even in these cases the effective work is attributed mainly to the egg parasite *Trichogramma* spp., and the (probably introduced) *Ascogaster quadridentatus*. The larvae and pupae of the pest have attracted strikingly few native parasites, and those species which have attacked this host never appear to build up high populations.

DISCUSSION

The results of the foregoing survey for native parasites and predators of the codling moth larvae and pupae in California reveal that the position there is little better than that found by similar investigations in other sections of N. America. Some of the orchards examined have been untreated for as long as 15 years, yet the populations of the few native natural enemies seem to have remained very low while the resident codling moth population has remained relatively high and caused considerable annual crop losses to the growers. Though of sporadic distribution, the introduced species *Ascogaster quadridentatus* is probably the most effective larval parasite in the state. The native Tachinid *Lixophaga orbitalis* did not build up appreciable populations in the course of the 1941 season though it was present early in the year in most areas investigated; there

is good reason to believe that the species is already exerting its maximum effect on the host. The ectoparasitic species of *Aenoplex* on the spun up larvae are not well adapted to exercise appreciable control on the host because of the intervention of a diapause in their life histories at a time when the codling moth is rapidly building up, and moreover, doing all the economic damage. Further, the Ichneumonid's very low incidence in the summer broods of the codling moth suggests that other hosts may be utilized in this period.

The rather sharp contrast between some of the data obtained in the present work and those of Flanders (13 to 16) is possibly due to two factors. Firstly, the intensification of insecticide treatments since that time may have greatly reduced the native parasite populations, and, secondly, the samples taken by Flanders may have been too small for a true representation of the part played by parasites. A reasonable statement of the position in regard to the role of natural enemies of codling moth in California is that of Quayle (21) and Boyce (5) that they are not of sufficient effect to warrant much consideration in the control program.

It has been remarked above that in this lack of any effective controlling action by native parasites and predators, the position in California appears similar to that in other parts of N. America. There are some data to show that, under favourable conditions, egg parasitism by *Trichogramma* spp. becomes high late in the season in a few areas in America, but for satisfactory control these parasites should destroy a high proportion of the eggs when the host populations are low, and this they are apparently unable to do. The action of the native larval and pupal parasites and predators, however, is even more unsatisfactory since there is no evidence that they destroy a high proportion of the host even when the latter is abundant. On the basis of published data and the present survey in California, it might almost be claimed that these species are little more than "casual" enemies of the codling moth. In view of the long period during which the moth has been recognized as a pest in N. America, the behaviour of the native enemies is discouraging and there is no reason to expect any improvement.

The question of the desirability of introducing any of the Californian species into Canada requires only brief notice in view of the ineffective nature of these forms. *Aenoplex carpocapsae* is known to occur in the central Appalachian range, Illinois, etc., and as there are no obvious geographical barriers to its spread into Canada, its absence (or extreme rarity) there is probably due to some other natural factors. In California this species is not more abundant than in some of the eastern states, and it is very doubtful if any useful purpose would be served by liberating colonies in Eastern Canada. The Tachinid *Lixophaga orbitalis* is said by Reinhard to be known only from California but it has already been noted that considerable taxonomic confusion obtains regarding the identity of the *Lixophaga* species which have been reared from codling moth in eastern and western states. It is therefore possible that the species already exists in the East, though apparently with a lower incidence than in California, and its liberation in Canada might thus be worth a trial. The Clerid and Raphidid predators were not recovered in Boyce's survey in the Niagara district, and these also deserve consideration for introduction.

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NOTES ON THE LONGEVITY, SPORULATION AND DIAGNOSIS OF *BACILLUS LARVAE*, THE CAUSE OF AMERICAN FOULBROOD OF BEES[1]

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In the diagnosis of American foulbrood of bees it is important to supplement microscopic examination of suspected samples with cultural tests to establish the identity of the causal organism, *Bacillus larvae*. Cultural tests are imperative in determining the presence of viable spores in comb which has been subjected to treatment by heat or chemicals. For successful cultivation *in vitro* of *B. larvae* special media are required, the organism failing to grow on ordinary laboratory substrates. The earlier media employed contained such substances as crushed brood or egg yolk. In this laboratory more easily prepared media containing peptone, yeast extract and carrot or turnip extract have been found useful in the routine diagnosis of American foulbrood (2, 3, 4). In a more recent study of the growth requirements of *B. larvae* (5) a simple medium containing peptone and thiamin was found to permit good growth of the organism.

The viability of *B. larvae* on artificial media has been consistently noted to be poor. The majority of the vegetative cells die and undergo autolysis so that transfers made after 2 weeks or more are frequently sterile. This poor viability is doubtless related to the difficulty in inducing spore formation *in vitro*, in spite of the fact that in samples of foulbrood scale as ordinarily found, the organism consists entirely of spores. In the earlier studies of *B. larvae*, White (13) recognized the difficulty in obtaining spores on certain laboratory media, especially those containing sugar. Tarr (9) reported improved spore production by inclusion of a phosphate buffer in a medium to neutralize acid formation from sugar. Holst and Sturtevant (1) proposed a medium for stock cultures as well as for the production of spores. Though permitting abundant growth of the organism this medium (which contains 1% glucose) has not given good results in our hands from the standpoint of maintaining viability or that of spore production. The experiments here reported were planned to study further certain factors affecting longevity and sporulation of *B. larvae* and also its cultivation from foulbrood scale.

EXPERIMENTAL

Longevity of Bacillus Larvae

The viability of *Bacillus larvae* was studied using two media, peptone yeast carrot extract agar (3), and peptone thiamin agar (5), each prepared with and without the addition of 1% glucose. Six strains of the organism,

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freshly isolated from scale, were inoculated in triplicate to slants of each medium. After incubation at 37° C. for 4 days, the tubes were plugged with cork stoppers and stored at room temperature. A similarly prepared series was stored at 4° C. Periodic transfers were made by 1 mm. loop inoculation to tubes of yeast carrot semi-solid agar, and cultures observed for growth and nitrite formation after incubation at 37° C. for 2 weeks.

TABLE 1.—LONGEVITY OF *Bacillus larvae* ON AGAR MEDIA*

Storage (days)	Peptone yeast carrot extract agar		Peptone thiamin agar	
	+ glucose	− glucose	+ glucose	− glucose
	storage at room temperature			
10	17	18	15	18
20	8	18	4	18
30	8	18	8	18
50	5	13	5	14
	storage at 4° C.			
10	14	18	15	18
20	6	11	2	8
30	5	14	3	14
50	4	8	0	7
75†	8	18	9	17

* Figures indicate number of tubes showing growth on transfer to yeast carrot semi-solid agar (18 cultures tested, 6 strains in triplicate).
† Very heavy inoculum.

Results of this test, summarized in Table 1, indicate the unfavourable effect of glucose on the viability of *B. larvae* on both media and at both temperatures. With all modification of the media decreased viability was noted within 50 days. Storage at room temperature was rather more favourable to longevity than that at 4° C. With a particularly heavy inoculation, made after 75 days, it was possible to demonstrate the presence of viable cells in a greater number of cases. However, the unfavourable effect of glucose was still evident.

Further evidence of the effect of glucose is noted in Table 2, giving results from a similarly conducted test of 13 strains of *B. larvae* grown on the "stock culture" medium of Holst and Sturtevant (1) and on a similar medium without glucose. Six of the strains failed to grow when transferred after 45 days' storage at 4° C. on the stock medium (containing glucose), though all remained viable after 120 days in the absence of glucose.

TABLE 2.—EFFECT OF GLUCOSE ON LONGEVITY OF STRAINS OF *B. larvae* ON PEPTONE YEAST EXTRACT AGAR*

Strain	45 days at 4° C.				120 days at 4° C.			
	+ glucose		– glucose		+ glucose		– glucose	
	Growth	NO_2	Growth	NO_2	Growth	NO_2	Growth	NO_2
A	4	+	4	+	4	+	4	+
B	3	+	3	+	4	+	4	+
C	4	+	4	+	4	+	4	+
D	4	+	4	+	4	+	4	+
10	4	+	4	+	4	+	4	+
20	0	–	3	+	0	–	4	+
21	0	–	4	+	0	–	4	+
U	0	–	3	+	0	–	4	+
V	0	–	4	+	0	–	4	+
W	4	+	4	+	4	+	4	+
X	0	–	3	+	0	–	4	+
Y	4	+	4	+	4	+	4	+
Z	0	–	2	+	0	–	4	+

* 0, 1, 2, 3, 4 = degrees of growth on transfer to yeast carrot semi-solid.

To study the longevity of *B. larvae* in soil, 2.5 ml. amounts of cell suspensions in water from 72-hour slant cultures on "stock" medium were added to 10 gm. of finely ground, sterile soil in 125-ml. Erlenmeyer flasks, plugged with cotton to permit desiccation and kept at room temperature. Six strains were tested in duplicate. Viability tests were made at intervals by transferring two 3-mm. loopfuls to yeast carrot semi-solid. The data in Table 3 indicate a decrease in viability with all strains after 50 days. However, use of a heavy inoculum (10 loopfuls) showed the presence of viable cells after 228 days.

TABLE 3.—LONGEVITY OF 6 STRAINS OF *Bacillus larvae* IN DRY SOIL*

Storage (days)	Strain of *B. larvae*											
	A		B		X		10		20		21	
	Growth	NO_2	Growth	NO_2	Growth	NO_2	Growth	NO_2	Growth	NO_2	Growth	NO_2
20	4	+	4	+	4	+	4	+	4	+	4	+
30	4	+	3	+	4	+	3	+	4	+	4	+
50	2	+	0	–	2	+	0	–	0	–	0	–
75†	4	+	4	+	4	+	4	+	4	+	4	+
158†	4	+	4	+	4	+	4	+	4	+	4	+
228†	4	+	4	+	4	+	4	+	4	+	4	+

* 0, 1, 2, 3, 4, = degrees of growth on transfer to yeast carrot semi-solid.
† Very heavy inoculum.

Spore Production

In the preceding tests microscopic examination of the cultures showed that spore formation was almost entirely suppressed in all cases where glucose was added. Without added glucose, spore formation was generally abundant with indications of considerable strain variation. Of the media

tested, "stock" medium of Holst and Sturtevant, prepared without glucose, was the most reliable for spore production. In Table 4 are presented results from a test with 13 strains of *B. larvae* grown on "stock" medium, with and without glucose, including a duplicate series in which culture tubes were stoppered immediately after inoculation. Whereas spore formation was inhibited in the presence of glucose, it was evident in all cultures when sugar was absent, being specially abundant in the sealed tubes. This test was repeated with 12 fresh isolates of *B. larvae* and similar results obtained.

TABLE 4.—SPORULATION OF *Bacillus larvae* ON PEPTONE YEAST EXTRACT AGAR AS AFFECTED BY GLUCOSE AND SEALING OF CULTURE TUBES*

Strain	Glucose added				No glucose			
	Sealed		Unsealed		Sealed		Unsealed	
	6 days	12 days	6 days	12 days	6 days	12 days	6 days	12 days
A	0	0	0	0	4	4	2	3
B	0	0	0	0	4	4	2	3
C	0	0	0	0	4	4	3	4
D	0	0	0	0	4	4	4	3
10	0	0	0	0	4	4	4	4
20	0	0	0	0	2	3	1	2
21	0	0	0	0	4	3	2	2
U	0	0	0	0	2	2	2	1
V	0	0	0	0	4	4	2	3
W	0	0	0	0	4	4	2	3
X	0	0	0	0	4	4	2	3
Y	0	0	0	0	4	3	3	2
Z	0	0	0	0	4	4	1	3

* 0, 1, 2, 3, 4, = degrees of sporulation.

In an attempt to explain the favourable effect of sealing, 48-hour cultures on "stock" agar without glucose were transferred to an atmosphere of CO_2 and also to one in which oxygen was removed by suction and pyrogallic-potash. Further growth and sporulation were suppressed in both cases, while in the latter environment most vegetative cells rapidly disintegrated leaving the pre-formed spores in the free state.

Comparison of Diagnostic Media

For the purpose of diagnosis of American foulbrood in suspected samples of comb a medium giving prompt development from small inocula of spores is desirable. The chief media employed for this purpose have contained crushed brood (6, 11), egg yolk (12), egg yolk and yeast (7), yeast and carrot or turnip extract (2, 3, 4) chicken embryo (10), and yeast carrot extract and cysteine (1). Some of these substrates such as those made from brood, egg, or embryo, are more difficult to prepare and have the disadvantages of being opaque and not suited to pressure sterilization, making them less satisfactory for routine use.

A comparison was made of the more simply prepared media, to study the effect of including various ingredients on the ability of the substrate to permit growth of inocula containing different numbers of spores from

foulbrood scale. To a basal inorganic solution (5), peptone 1%, glucose 1%, yeast extract 0.5% and carrot extract, 200 ml. per litre (3) were used in the combinations indicated in Table 5 to prepare semi-solid (0.3% agar) media. From a suspension of crushed scale, standardized by direct microscopic count, dilutions were prepared containing from 40 to 4,000,000 spores of *B. larvae* per ml. One ml. of each dilution was used as inoculum.

TABLE 5.—COMPARISON OF SEMI-SOLID MEDIA FOR DETECTION OF *Bacillus larvae* IN SUSPENSIONS OF CRUSHED SCALE

Medium	Number of spores in scale suspension (per ml.)					
	4×10^6	4×10^5	4×10^4	4×10^3	4×10^2	4×10^1
Peptone	0	0	0	0	0	0
Peptone, glucose	3	2	1	0	0	0
Peptone, yeast	3	3	3	2	3	1
Peptone, yeast, glucose	3	3	3	3	3	3
Peptone, carrot	2	0	0	0	0	0
Peptone, carrot, glucose	3	1	2	0	0	0
Peptone, yeast, carrot	3	3	3	3	3	3
Peptone, yeast, carrot, glucose	3	3	3	3	3	3

Figures represent number of positive tubes (out of 3).

Development of *Bacillus larvae* after 10 days' incubation at 37° C., as indicated by macroscopic growth and a positive nitrite test, is shown in Table 5. Three of the media, all containing yeast, were positive with all tubes inoculated with the most dilute spore suspension. Glucose, though detrimental to longevity and spore production, exerted a favourable effect in the absence of yeast in media designed for diagnostic purposes.

TABLE 6.—EFFECT OF MEDIUM AND TIME OF INCUBATION ON DEVELOPMENT OF SPORES OF *Bacillus larvae* FROM DILUTE SUSPENSIONS OF CRUSHED SCALES

Spore count per ml.	Medium	No. of of tubes	Number of tubes positive		
			5 days	10 days	15 days
3.6	Peptone yeast glucose semi-solid	10	8	9	
	Peptone yeast carrot semi-solid	10	9	9	
	Peptone yeast carrot glucose semi-solid	10	8	8	
	"Diagnostic medium" (solid)*	10	5	8	
3.6	Peptone yeast carrot semi-solid	50	15	38	46
	"Diagnostic medium" (solid)	50	9	44	47
4.1	Peptone yeast carrot semi-solid	50	20	22	22
	"Diagnostic medium" (solid)..........	50	4	13	15

* Holst and Sturtevant.

Further tests on the ability of different media to initiate growth of *B. larvae* from dilute spore suspensions from scale are summarized in Table 6. The data show results from tests with three different scale suspensions. One ml. of inoculum was used, added to the semi-solid medium

and incorporated by shaking, and, in the case of the solid agar, to slants which were then incubated upright. While the percentage of positive tubes varied with the scale suspension, and is probably related to the number of "non-viable" spores present, the semi-solid media gave in all cases a noticeably greater proportion of positive tubes after the shortest incubation period. With more prolonged incubation such differences tended to disappear. The data support the findings of Sturtevant (8) who showed that seedings of smaller numbers of spores frequently require a prolonged incubation before vegetative growth is produced.

Using a slanted solid medium containing yeast, carrot and egg yolk, to which 1 ml. of inoculum was added, Sturtevant (8) found that a minimum of 50,000 spores was required to produce vegetative growth. Later Holst and Sturtevant (1) state, without presenting data, that with their "diagnostic medium" the lag phase preceding germination is greatly reduced, as compared with egg-yolk medium, and that with the former growth may occur "with an inoculum of one or only a few spores". Tarr (10) using a chicken embryo medium, obtained growth with inocula containing 1,000, and in some cases as few as 100 spores.

Since our medium and the "diagnostic medium" of Holst and Sturtevant both contain peptone, yeast, and carrot extract it is felt that the advantage of the former in initiating more rapid germination of small numbers of spores is largely due to its being semi-solid. It has been consistently our experience that development in semi-solid begins slightly below the surface, suggesting that here more suitable conditions for germination obtain than in the liquid-solid system of the slanted agar cultures. The inclusion of inorganic salts may also be of value in the semi-solid media.

SUMMARY

The incorporation of glucose in media for the cultivation of *Bacillus larvae* noticeably decreased the longevity of the organism. In dry soil it was found viable when tested after 228 days.

Sporulation was almost completely suppressed in the presence of glucose. Media without added sugar were suited to spore formation which was noticeably favoured by sealing the culture tubes.

A semi-solid medium containing peptone, yeast, and carrot extract permitted more rapid germination from inocula of small numbers of spores (less than 5) than a solid medium containing these ingredients. Consequently this semi-solid medium is recommended for the diagnosis of *B. larvae* in comb suspected of containing American foulbrood.

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DETERMINATION OF FLESHING CHARACTERISTICS IN MARKET POULTRY[1]

II. TURKEYS

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Two of the most striking features of dressed turkeys are their abruptly prominent keel and their characteristically slabsided appearance. In recent years the Broad Breasted and the Beltsville Small White breeds have added a new feature to the turkey population of this continent in so far as in both cases the breasts of the dressed carcasses present a decidedly more rounded and fleshy appearance than is the case with the more familiar breeds. This difference is so marked and potentially of such economic importance that an inquiry into its nature was undertaken. The immediate concern of this investigation was to determine whether slabsidedness in turkeys is caused by the inordinately prominent keel or is of muscular origin, and whether the factors involved are amenable to selection.

Apparently Jull (7) was one of the first to draw up a definitely formulated program for improvement of fleshing characteristics of turkeys. He stated his objective as being "a relatively short-legged, long-bodied, early-maturing, good-fleshing type of white feathered turkey". Through a market survey Smith (10) determined at this time (1935) that the popular demand was for a medium sized turkey from 11 to 14 pounds. The Beltsville Small White variety was apparently the outcome of these various considerations. Later Jaap (4) and Jaap and Penquite (5) studied the conformation of body shape by expressing linear body measurements as ratios of the cube root of body weight. By virtue of such ratios a differential shape response of individual breeds to different degrees of fleshing was found in rib spread, anterior depth and shank length. Jaap, Thompson and Milby (6) found that by selecting parents for proportionately short shanks, long keels and shallow bodies, progeny was obtained which excelled in body weight. However, in view of the questionable nature of Jaaps ratios, which has been discussed by Lerner (8, 9) and mentioned by Bird (3) the significant observation seems to be that, throughout all the breeds that were studied, the birds which were adjudged to show a superior degree of fleshing were at the same time those that reached the greatest average body weight for each breed. Asmundson and Lerner (1) found that the weight of the pectoralis major was more dependent on the length of the underlying sternum than on length of leg. Bird (3) showed that the entire musculature dissected off the pectoral region and the posterior extremities of White Leghorn and Barred Plymouth Rock roasters was closely correlated to the deviation of observed from expected body weight relative to length of tibia. Such deviations, which were termed "fleshing indices", were however found to be unreliable estimates of roundness of breast since this characteristic depended fully as much on the depth through the

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thoracic girdle as upon absolute volume of fleshing. Thus an excessively deep bodied bird might present a quite slabsided appearance in spite of a high fleshing index, while a shallow carcass could be fairly deficient in fleshing and still be very attractively round in the breast. Since fleshing indices and thoracic depth both showed familial segregation in Barred Plymouth Rocks it was hoped that application of this technique to several breeds of turkeys might yield similarly reliable determinants of their fleshing and appearance and thus facilitate progeny testing for these characteristics in turkeys.

MATERIAL AND METHODS

Eighty birds were used in this study, including 20 males of each of three breeds, Standard Bronze, Broad Breasted and Beltsville Small White, and 5 Bourbon Red males and 15 Standard Bronze females. All birds were of the same age and raised under comparable conditions in adjoining runs and on identical feed which, in the starter ration contained 25% protein and 22% in the growing ration. It was intended to kill the birds at 27 weeks of age but on account of heavy snow storms this had to be postponed till the 29th week. The procedure when collecting the data was as outlined previously for chickens (3). The birds were measured, and after starving over night they were weighed, killed, dressed, graded and placed in cold storage. On removal from storage, tracings were made of cross-sections which were cut just forward of the anterior point of the keel; the entire musculature was then dissected off the pectoral region and the posterior extremities and weighed. No attempt was made to secure the weight of the skeleton and consequently no determination of total edible portion was made. As a ready reference a tracing from each breed is reproduced in Figure I. The tracings depict in each case a bird that, for each breed, yielded the mean weight of muscle and was possessed of approximately the mean depth of torso. Thus the shape and degree of fleshing of each tracing are typical of each breed as represented by the available samples.

FLESHING OF BREAST

From the individual sections of each breed the measurements along the median line from A to B and from B to C, as shown in Figure I No. 5, were obtained. These data are presented in Table 1.

TABLE 1.—MEAN DEPTHS THROUGH THE THORACIC GIRDLE

		Depths			$\frac{AB \times 100}{BC}$
		A C	B C	A B	
		mm.	mm.	mm.	
20 Bronze	Males	233.9	143.5	90.4	63.12
20 Broad Breasted	Males	233.4	139.1	94.3	68.04
5 Bourbon Red	Males	212.5	131.4	81.1	62.34
20 Small White	Males	202.6	119.4	83.2	69.75
15 Bronze	Females	185.5	111.2	74.3	66.92
50 Barred P. Roc,	Males	131.2	85.8	45.4	52.91

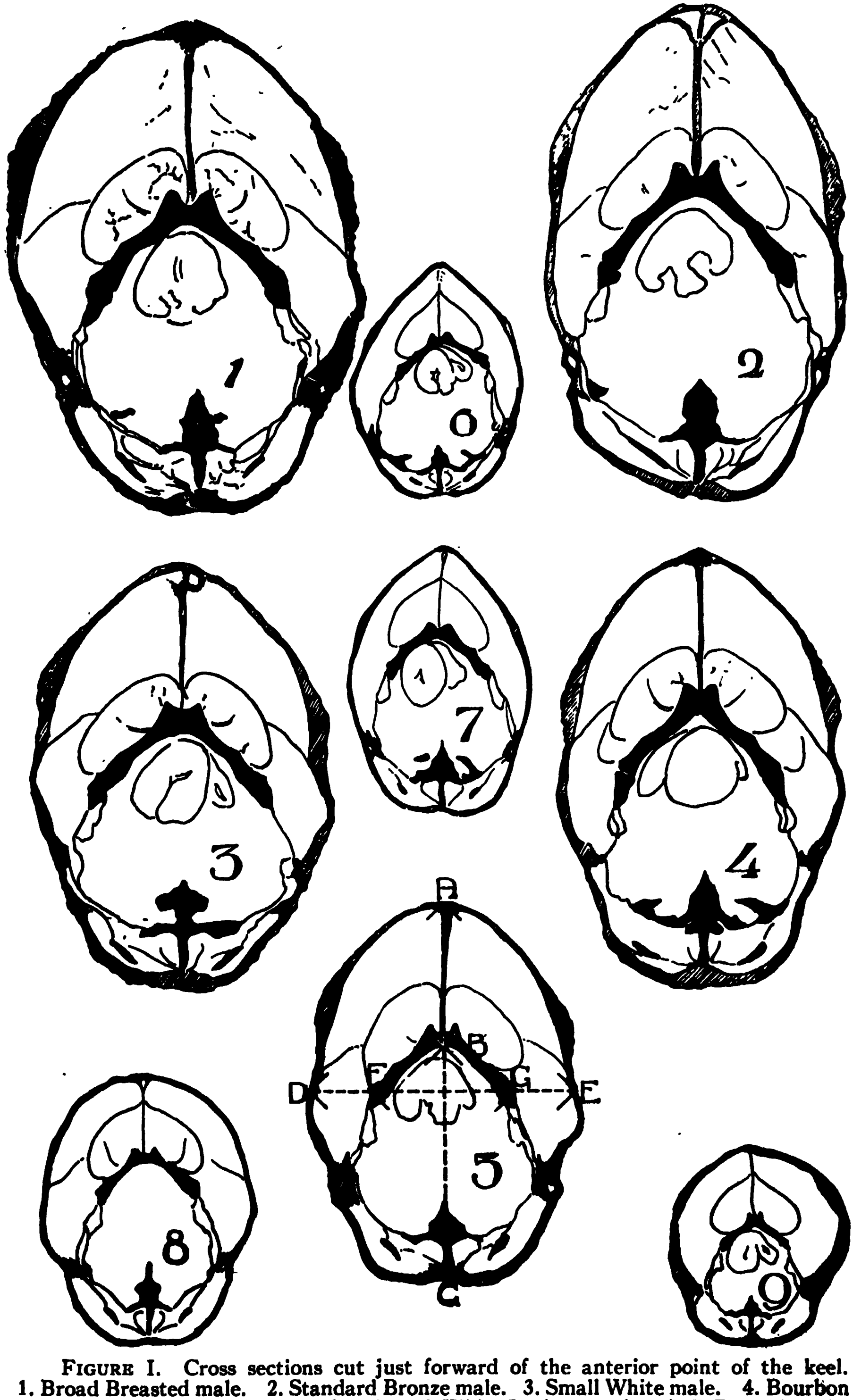

FIGURE I. Cross sections cut just forward of the anterior point of the keel. 1. Broad Breasted male. 2. Standard Bronze male. 3. Small White male. 4. Bourbon Red male. 5. Standard Bronze female. 6. White Leghorn male. 7. B.P. Rock male. 8. Dark Cornish male. 9. Ringneck Pheasant male. Reduced to 29.2% of natural diameter.

The tracings show that at this section through the torso the pectoralis major extends over the side of the bird to the level of the vertebral hemal spine and that it is thickest and aids in creating the maximum width of the bird at the level at which the pectoral skeleton articulates with the ribs.

Males of the Bronze and Broad Breasted breeds are markedly different in roundness of breast contour but are of equal body depth from A to C. However the former breed has a deeper cavity and hence a lower keel than found in the Broad Breasted as shown by the ratio of AB to BC. An analysis of the individual percentages, after their transposition to degrees of an angle, revealed that in this respect the five breeds segregated into two highly significantly different homogeneous populations. Thus the Small White and Broad Breasted males and the Bronze females, all of which are quite round in breast conformation, are proportionately deeper in keel than the Bronze and Bourbon Red males. The significance of this observation is that the breeds and the sex, as judged by the one available sample, which have the roundest breast are possessed of a pectoral skeleton which potentially will accommodate a proportionately greater volume of muscular tissue than is found on more slabsided breeds.

In an endeavour to estimate the thickness of fleshing over the breast the total width of torso from D to E and width of pectoral skeleton from F to G, as shown in Figure I No. 5, was measured at this level. Hence the combined thickness of the two pectoralis major muscles could be obtained by difference. These data and the relationship of thickness of muscle to width of skeleton are presented in Table 2 and serve as approximate estimates of fleshing over the breast.

TABLE 2.—MEAN WIDTHS THROUGH THORACIC GIRDLE

		Widths			$\frac{DF + GE \times 100}{FG}$
		DE	FG	DF + GE	
		mm.	mm.	mm.	%
16 *Bronze	Males	135.2	89.4	45.8	51.33
17 *Broad Breasted	Males	159.0	90.8	68.2	75.11
5 Bourbon Red	Males	132.2	77.8	54.4	69.92
13 *Small White	Males	139.3	76.1	63.2	83.05
10 *Bronze	Females	123.5	65.7	57.8	87.98

* Birds the contour of which had been distorted by pressure during storage were excluded from this analysis.

Analysis of these data revealed that Bronze females and Small White males are possessed of superior relative thickness of flesh and do not differ materially from one another in this respect. Broad Breasted and Bourbon Reds form a slightly inferior class while Bronze males are characteristically thin in musculature of the breast. Thus the average apparent fleshing of the breast of these four breeds of turkeys is in fact an approximate measure of their average actual fleshing since muscles tend to become thicker and the breast rounder from one breed to another as the keel that is to be covered becomes deeper. These observations express breed differences. However as will appear later, within breeds the same relationship holds which was found for chickens, namely, that a shallow torso relative to volume of muscle tends to produce a rounded breast.

The Standard Bronze is unquestionably the most important breed on this continent by virtue of its numerical preponderance over all other breeds. It is therefore a misfortune that among turkeys, a species which is raised exclusively for meat purposes, the pectoral skeleton of the principal breed is so shallow that it accommodates a rather small volume of muscle which when stretched over a relatively deep torso results in a carcass which is typically narrow and slabsided.

FLESHING IN GENERAL

The data which are necessary for an analysis of general fleshing characteristics of the several breeds of turkeys are presented in Table 3. For the sake of comparison, data on three breeds of chickens and on a small sample of Ringneck Pheasants are included.

TABLE 3

		Live body weight	Tibia length	Torso depth	Muscles				
					Breast	Legs	Br.+Legs	Legs as % of Br.	Legs+Br. as % of remainder
		gm.	mm.	mm.	gm.	gm.	gm.	%	%
20 Bronze Breasted	Males	11277	248.3	233.4	2224.4	1884.0	4108.4	84.7	57.60
20 Bronze	Males	9625	264.0	233.9	1770.2	1675.1	3445.3	94.6	55.40
5 Bourbon Red	Males	8331	238.8	212.5	1480.9	1320.6	2801.5	89.2	50.51
20 Small White	Male	7916	224.3	202.6	1409.1	1204.6	2613.7	85.5	49.34
15 Bronze	Females	5971	212.3	185.4	1117.9	1024.8	2142.7	91.7	56.12
50 B.P. Rock	Males	3082	180		386.1	620.3	1006.4	160.7	47.03
55 W. Leghorn	Males	2137	156		254.6	378.9	633.5	148.8	42.17
5 Cornish	Males	3232	161		510.2	708.8	1219.0	138.9	60.45
3 Pheasant	Males	1201	122		294.7	256.5	551.2	87.0	70.53

It is of interest to note the proportion of weight of leg muscle to that of the breast. In walking birds the breast is relatively poorly developed whereas the opposite is the case for those of a flying habit. Furthermore, these ratios confirm the statement above that Bronze turkeys have the poorest while Broad Breasted and Small Whites have the heaviest development of breast muscle. The mean ratios of the combined weights of breast and leg muscles to weight of the remainder of the starved live weight of birds of the same sex become greater as the breeds show a heavier mean weight of body. This association may mean that internal organs are more stable in weight from one breed to another than is the weight of muscle and it holds between males of all breeds from Broad Breasted turkeys to White Leghorn chickens as shown by a $+0.970$ coefficient of correlation. However, within breeds the correlation is entirely non-existent as measured by the coefficient -0.085. This observation in conjunction with the facts that Bronze females show the same relative muscular development as do the males of that breed, that the regressions for turkeys and for chickens, although of similar slope, are not in linear continuation of one another and finally, that Cornish and Pheasants are so radically different from other classes all indicates that the relationship of muscular weight to remainder is governed by definite species and breed differences.

From the data the means of which are presented in Table 3 were obtained the statistical standards which are presented in Table 4.

TABLE 4

		log regression x = log body weight y = log tibia length	Correlation coefficients: Log tibia length to log body wt.	Muscle to index	Muscle to remainder	Br.- to leg muscle
20 Broad Breasted	Males	$x = 3.26971 + .32601y$	.063	.472	.486	.604
20 Bronze	Males	$x = 2.19054 + .74017y$	.225	.271	.535	.631
5 Bourbon Red	Males	$x = 1.39232 + 1.06316y$	.551	.676	.861	.673
20 Small White	Males	$x = 1.78781 + .89656y$	.342	.938	.745	.637
15 Bronze	Females	$x = 2.46376 + .56364y$	.229	.758	.468	.757
50 B.P. Rock	Males	$x = 1.06055 + 1.07904y$	.340	.938	.839	.867
55 W. Leghorns	Males	$x = .71778 + 1.84162y$	.720	.912	.906	.868

Assuming that the density of all birds is approximately equal, the proportionate length of leg to volume of torso may be read directly off the regression coefficients. Thus the Broad Breasted turkey has proportionately the shortest legs and is followed in order by Bronze females, Bronze males, Small Whites, Bourbon Reds, B.R. Rocks and White Leghorns, these latter having proportionately the longest legs.

From the regression equations were obtained the expected body weight of each bird relative to its length of tibia, and thus the deviations between these and the observed body weights i.e. the fleshing indices. Table 4 shows that only in the case of the Small White turkeys did the indices predict the actual weight of fleshing of breast and legs with the useful accuracy which was found for chickens. In view of this fact it becomes meaningless to employ either such regressions or simple ratios of anatomical measurements to body weight for the purpose of determining fleshing of any of the turkeys considered, or as bases for estimation of attractive appearance excepting only the Small White breed.

All birds were, as mentioned, alignment graded after dressing. This form of grading is in fact the most accurate estimate obtainable of roundness of breast as shown by the close agreement between rank numbers that were obtained by grading and by independent visual estimate of the tracings of sections. Rank numbers for the Small Whites which expressed the relationship between depth of torso to fleshing indices were found to be in substantial agreement with the results of alignment grading. In the case of other breeds in which the indices did not measure fleshing with appreciable accuracy, and the correlation between weight of breast and leg muscles was low, calculated grading could not be expected to succeed. However, when the actual weight of breast muscles rather than the index for these breeds was expressed as ratios to depth of torso similar satisfactory agreement between calculated and actual roundness of breast was obtained for these as for the Small Whites except in the case of the Standard Bronze males. In this one breed depth of the torso is so highly correlated to weight of breast muscle that slabsidedness becomes fairly uniform. It can therefore be stated as a general rule that within breeds roundness of breast is dependent on depth of torso.

DISCUSSION

It has been shown that a full development of pectoral musculature of poultry generally is dependent on a deep keel, and hence the low keel of walking birds is accompanied by poorly developed muscles of the breast. Also, that the breeds possessing the greatest relative weight of breast muscles and therefore the deepest keel are those with the most attractively rounded breast. In addition, the heavier a breed is the higher will be the average ratio of muscular tissue to waste. However, within breeds shallowness of torso tends to produce roundness of breast, and likewise within breeds proportion of flesh to waste is independent of the individual body weight although fluctuating within the predetermined breed limits. It therefore appears that the most desirable type of turkey must have maximum depth of keel with a sufficiency of flesh to cover this frame abundantly, thus producing a large and heavy bird. Within this type the shallowest torso will produce the roundest breast and females will tend to be more fleshy and round in breast than the males.

One important requisite for success of the fleshing index technique is a low degree of correlation between tibia length and body weight. In case of a close association here the deviations of observed from expected body weights will be so small that minor experimental errors in dissection or variations in emptying of the alimentary tract during the starvation period may obliterate the correlation of the indices to the actual weight of musculature. Furthermore, even when the correlation remains intact familial segregation may be endangered as was the case with the White Leghorn males (3). For this reason there will be more likelihood of success with birds that have passed the age of active skeletal growth when dispersal from the regression line increases markedly as shown by Asmundson and Lerner (2) and by the log correlation coefficients presented in Table 4, which are in close accord with most of the coefficients for birds after 16 weeks of age as shown by these authors.

The other requisite for success is a practically perfect prediction of muscular weight by the index. Some reasons why turkeys mostly fail in this respect are suggested. The use of tibia length as an index of skeletal size and of body weight as an index of fleshing has several implications. The first of these is the assumption that the weight of muscles of the legs and of the breast are highly correlated. It will be seen in Table 4 that this requirement is satisfactorily fulfilled by chickens, but rather poorly by turkeys. Furthermore, the correlation of combined weight of breast and leg muscles to the remainder of the starved live weight tends to be rather low for turkeys but of a high order for chickens. As a consequence total body weight can but rarely be a reliable measure of the weight of flesh which is present on the individual turkey, and hence the deviation of the observed from the calculated body weight cannot with certainty be expected to measure the relative degree of fleshing.

It is a misfortune that the fleshing index, though satisfactory for Barred Rocks, should be suited to estimation of fleshing in only one of the breeds of turkeys examined herein. In the absence of such precise information, selection of desirable fleshing type must rely on its subjective evaluation as presented in each individual.

CONCLUSION

Breeds, such as the Broad Breasted and the Beltsville Small White and the female sex in general, which have the roundest and most fleshy breasts have relatively the deepest keels. On the other hand the Standard Bronze males which have the same average torso depth as the Broad Breasted males are typically slabsided because of their deficiency and thinness of breast musculature. At the same time their keel is proportionately quite low. However, within breeds, the relatively shallowest torso is associated with roundness of breast conformation.

Birds of a flying habit such as turkeys and pheasants have a greater proportion of breast muscle to leg muscle than is found in walking species such as the chickens. At the same time the former have a proportionately much deeper keel than the latter.

The average ratio of muscular tissue to the remainder of starved live body weight increases from breed to breed as their mean weight of body increases. However, this relationship does not hold between individuals within the various breeds.

Turkeys are proportionate to their body weight, shorter in the legs than chickens. The heavy breeds are proportionately shortest in leg and the female leg shorter than that of the male.

Determination of fleshing by the fleshing index was accomplished with the same critical accuracy for Beltsville Small White turkeys as had previously been obtained for chickens. This was not the case for three other breeds of turkeys. The reasons for this have been discussed.

ACKNOWLEDGMENT

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BOOK REVIEW

LECTURES ON THE INORGANIC NUTRITION OF PLANTS. By D. R. Hoaglund, Professor of Plant Nutrition, University of California, 177 pages, 44 text figures, 28 plates; published by The Chronica Botanica Co., Waltham, Mass., U.S.A.; Wm. Dawson Subscription Agency, Ltd., Toronto, Ont. 1944. Price. $4.00.

The question of plant nutrition is such a broad one, involving so many different aspects, that a general survey of the subject presented in a condensed form is of great value. This has been accomplished in the publication by Professor Hoaglund which embraces the material of seven lectures, revised and supplemented, presented at Harvard University under the Prather Lectureship.

In the preface, the author says, "Obviously, this small volume cannot have any of the characteristics of a monograph or of a text. Its purpose is to present a general perspective of several important aspects of the field of plant nutrition, with a broad interpretation of the term in mind...... The limited scope of the lectures precluded consideration of a vast number of important contributions to the field surveyed."

In Lecture 1, a survey of the problems of plant nutrition is presented. The author comments "I doubt that there exists in any other system presented for scientific or practical study a comparable degree of complexity." Problems of the soil solution in relation to plant nutrition, the rôle of soil colloids, soil acidity and alkalinity in relation to plant growth, experiments by artificial culture methods, and climatic influences are some of the questions considered as an introduction.

The functions of micronutrient chemical elements in plant growth are taken up in the second lecture. Special attention is given to experiments in connection with studies on zinc. Some practical aspects of micronutrient problems are presented, with reference to animal as well as plant nutrition.

Lectures 3 and 4 cover the absorption and accumulation of salts by plant cells, and the upward movement and distribution of inorganic solutes in the plant in their relation to transpiration and to plant metabolism. The use of radioactive isotopes in following the movement of ions, and the importance of this relatively new method of investigation, are discussed. Although considerable work has been done, the present knowledge of salt movement in the plant is still inadequate.

The growth of plants in artificial media in relation to the study of plant nutrition is discussed in Lecture 5. Conditions for the growth of plants in artificial culture are given and the effect of aeration of nutrient solutions and of climatic factors on the growth of plants is presented.

Several aspects of the problems of chemical processes occurring in plant tissues as salt is moving into and through the cells are presented in Lecture 6. These include the buffer action within the plant which keeps

the hydrogen ion concentration within narrow limits, the relationship of organic acids to salt absorption, and metabolism and protein formation in relation to absorption of nitrogen. The author contends the biochemical attacks on plant nutrition will constitute one of the strongest trends of the future. Finally, in Lecture 7, certain aspects of the potassium nutrition of plants are given as illustrating problems of the system soil-plant-atmosphere.

The author has taken his illustrations largely from the work of the California scientists with which he is familiar. Plates and figures are used freely to illustrate the points discussed, and references are given to about 150 published articles. The book has apparently well fulfilled its purpose of presenting a general view of the field of plant nutrition.

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THE REPRODUCTION OF THE NUCLEUS[1]

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INTRODUCTION

Insects have long been and still remain a valuable source of material in the researches of the cytologist. By their study classical contributions have been made to the development of both chromosome cytology and genetics. Moreover, after a period of partial eclipse by plants during the past decade and a half, interest in insect cytology is once more being engendered. In their general uniformity of behaviour plants show the basic principles; insects supply, in their exceptions, the "natural experiments" (Darlington, 7) by which the former may be tested.

It is only within the last few years that the debt to the entomologist is being repaid (see Huxley, 14). It is unfortunate, therefore, that the entomologist is not always prepared to appreciate what he is offered, nor aware of what he can legitimately ask of the cytologist. The reason for this is manifold. Changes in the terminology dealing with chromosome cytology are a natural concomitant of the advances in knowledge that have been made since the majority of us graduated. Unfortunately many of these are confusing either because they resemble pre-existing words or because they are innately difficult to remember. Further, through constant repetition certain hypotheses have not infrequently gained acceptance as established fact (see Huskins, 13); the obvious specialized nature of the study often renders impossible a discrimination between fact and theory except by those constantly concerned with the problems at hand. Finally, there is absent from the literature a description aimed at synthesizing the vast amount of data accumulated from diverse fields without at the same time unduly subjugating them to a preconceived idea. In this outline I have used as much as possible the terminology that is in common use to describe and interpret (often hypothetically) what is seen under the microscope. With the meaning and connotation of the terms the entomologist must become familiar if he is to avail himself of the contributions to the problems of taxonomy and population genetics now being made.

An integration of the type assayed here would be difficult if concerned with so uniform a group as the plant kingdom; to attempt to cover fully so complex a group as the insects, and in a matter of a dozen or so pages, is little short of impossible. We are here concerned only with the funda-

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mentals: the object is to describe the essential facts and, in so far as is possible, to "explain" the cause. Factual exceptions of wide occurrence do not to the best of the writer's knowledge exist; the rare exceptions, because of lack of space, must here be ignored.

No claim is made that the outline presented would meet with the unqualified approval of the majority, nor even perhaps the minority, of cytologists, for, as is usual with the entomologist, the average cytologist is concerned with a particular plant or animal group and can sometimes put his finger on exceptions (real or apparent) in his material that appear to question the validity of the synthesized whole, and of which the synthesizer is unaware. At the same time, it is scarcely conceivable that the micro-mechanics of such long-established phenomena as mitosis and meiosis could have persisted unaltered in the changing world of biology: evolution is a datum of experience, it must not be expected to circumvent the mechanisms to which its products owe their origin. Even upon such substantial matters as the number of threads in a chromosome there is a singular lack of agreement (Sax and Sax, 22): some say one, some two and others four; and others again just "don't know." Such a divergence of opinion need perhaps occasion no alarm, for we are dealing with objects at the limit of microscopic visibility and, in the case of the "don't know" school, at least, with objects considerably below the powers of resolution of the compound microscope. Then there is the matter of chromosome dynamics: the daughter halves of a chromosome move apart and approach the poles. This much is seen, but how is the movement conditioned? There is no visible fibre connecting the chromosome half and the pole nor, following the results of micro-manipulation experiments, are there invisible *contractile* fibres; hence, there must either be attraction between the daughter chromosome and the pole or repulsion between the daughter halves. The weight of visual evidence favours the latter term for descriptive purposes; electrical potential differences known in living systems are of an order such that the repulsion forces are capable of effecting the movements ascribed to them (Haldane, unpub.).

The method of approach has been deductive-inductive. It is hoped that no undue emphasis has been given to the former, that no pertinent fact has been ignored; it is hoped, moreover, that the end-result will have both heuristic and propaedeutic qualities.

MITOSIS

With few exceptions chromosomes are present in duplicate in the fertilized eggs of insects, one set being derived from one parent, the other set from the other. The similar members of the two sets are said to be *homologous:* they have an ultimate common origin, and affect the same group of reactions in the life of the organism (Sharp, 25). The building up of the body, or *soma*, of the adult involves only about 20 to 30 cell-generations descended from the original single nucleus within the egg (White, 30). As we shall see, accompanying each division, or *mitosis*, of the cell into daughter cells, there is a longitudinal separation of the daughter halves of each chromosome; one daughter chromosome goes into one daughter cell, the sister half into the other. Further, the division of the cell is anticipated by one whole cell generation in the division, or more

correctly, the reproduction of the chromosome[3]. Between each division a *resting stage* intervenes, the active stages of mitosis being the *prophase, prometaphase, metaphase, anaphase* and *telophase.*

Resting[4] Stage

When not in an active stage of division, the killed, fixed, and stained nucleus, lying within its *nuclear membrane,* appears to consist of a granular substance within which are embedded two largish, more or less spherical bodies of higher density and refractiveness: these are the *nucleoli.* During the resting stage the nucleoli stain readily, the chromosomes do not[5]. As mitosis proceeds the nucleoli decrease in volume and the chromosomes become increasingly stainable, until, by metaphase, no sign of the nucleoli remains. It is difficult to avoid the conclusion that this is because, during prophase, the nucleoli give up to the chromosomes their stainable substance (though not necessarily chemically unchanged) and become reformed from the chromosomes during the subsequent telophase and resting stage. Accepting this view, the nucleolar material, at one time within the nucleolus and at another within the chromosomes, is always responsive to certain dyes. The transfer of this material from the chromosomes to the nucleolus (and the concomitant cyclical disappearance of the chromosomes) was responsible for the early controversy regarding the continuitv of the chromosomes from one division to the next. The belief that the chromosomes are formed *de novo* at each mitosis, like the belief that they are formed by the break-up of a "continuous spireme", has in various ways proved to be groundless.

Prophase

With the exception of the Diptera, the individual chromosomes are, from the very beginning of prophase, always double except at one point, the *centromere*[6] (Figure 1). The centromeres, the dynamic centres of the chromosomes, are grouped, or *polarized,* at one side of the nucleus. The two fine threads, or *chromonemata,* of which each chromosome is composed are, like electric flex, closely paired and twisted together throughout their length, that is, they are *relationally coiled,* and the whole is usually lying in a loose helix (*relic coil*). Apart from linear differences the individual chromosomes are distinguishable only in that two are each in contact at some point along their length with a nucleolus[7].

As prophase proceeds the chromosomes shorten but their total volume increases by taking up the material liberated by the nucleoli: the latter thus gradually diminish in size and finally disappear prior to metaphase. The overall length of the chromonemata in all probability undergoes little if any change, since the apparent shortening is largely due to each assuming the form of a tightly packed helix. This, the *somatic coil,* develops gradually, appearing first as numerous fine undulations, the number of which decreases as their amplitude increases (Figure 2). During this process the relational coil untwists and the larger and looser relic coil is completely

[3] See page 496.

[4] Syn. *energic:* a state of physiological activity without motion of the chromosomes (Berrill and Huskins, 3).

[5] See footnote 14.

[6] Syn attachment region; attachment constriction; insertion region; spindle fibre attachment; kinetochore (Sharp, 24) and kinomere (region) plus kinosome (body) of Huskins (unpub.).

[7] See footnote 14.

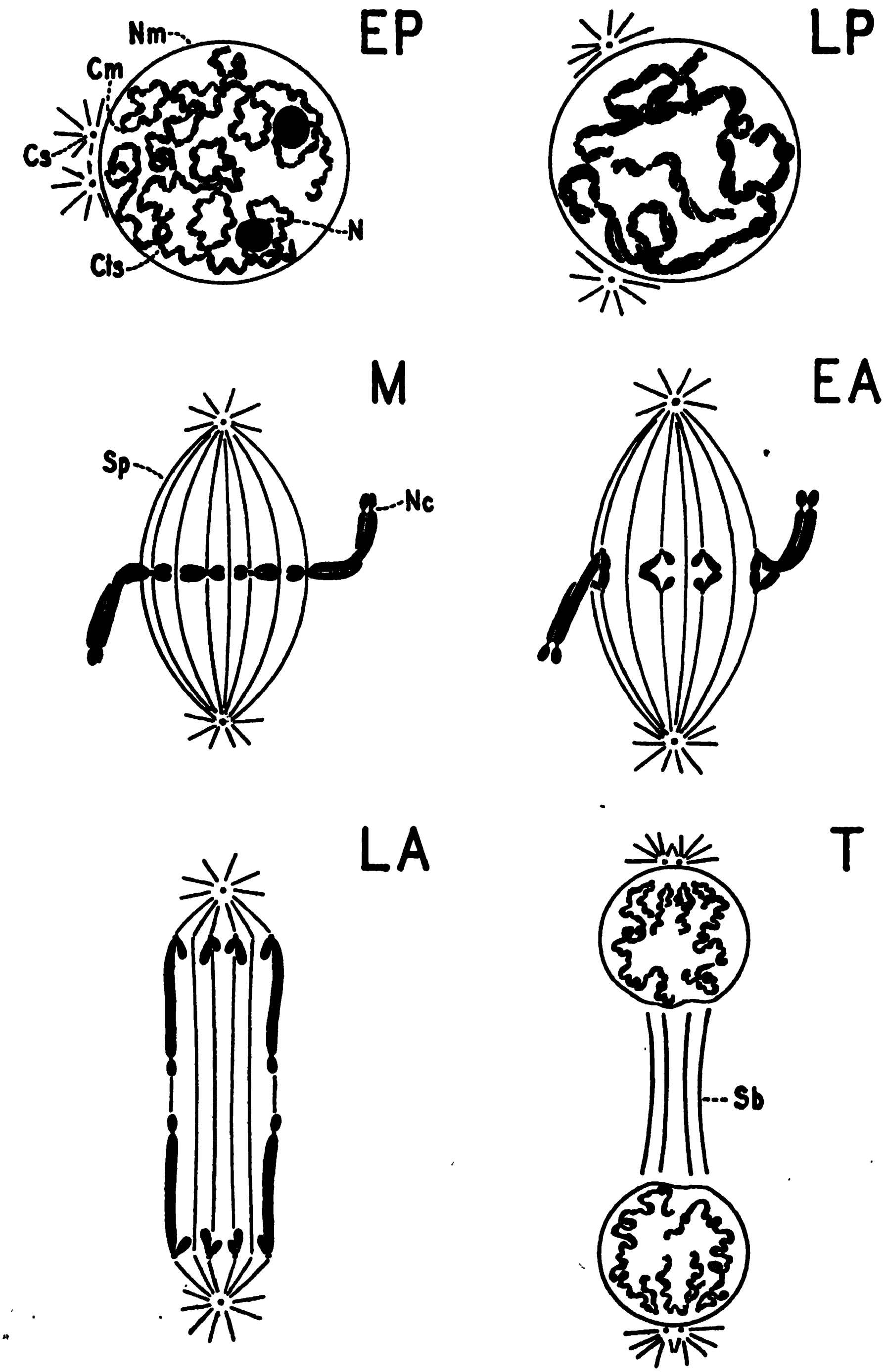


FIGURE 1. The mitotic cycle (excluding the resting stage) in a non-dipterous insect showing early prophase (EP), late prophase (LP), metaphase (M), early anaphase (EA), late anaphase (LA) and telophase (T). Both the relic and the relational coiling of the chromatids are resolved by metaphase. Cm = polarized centromere; Cs = separating daughter centrosomes; Cts = the two chromonemata of a chromosome; N = nucleolus; Nm = nuclear membrane; Sp = spindle; and Sb = stem-body.

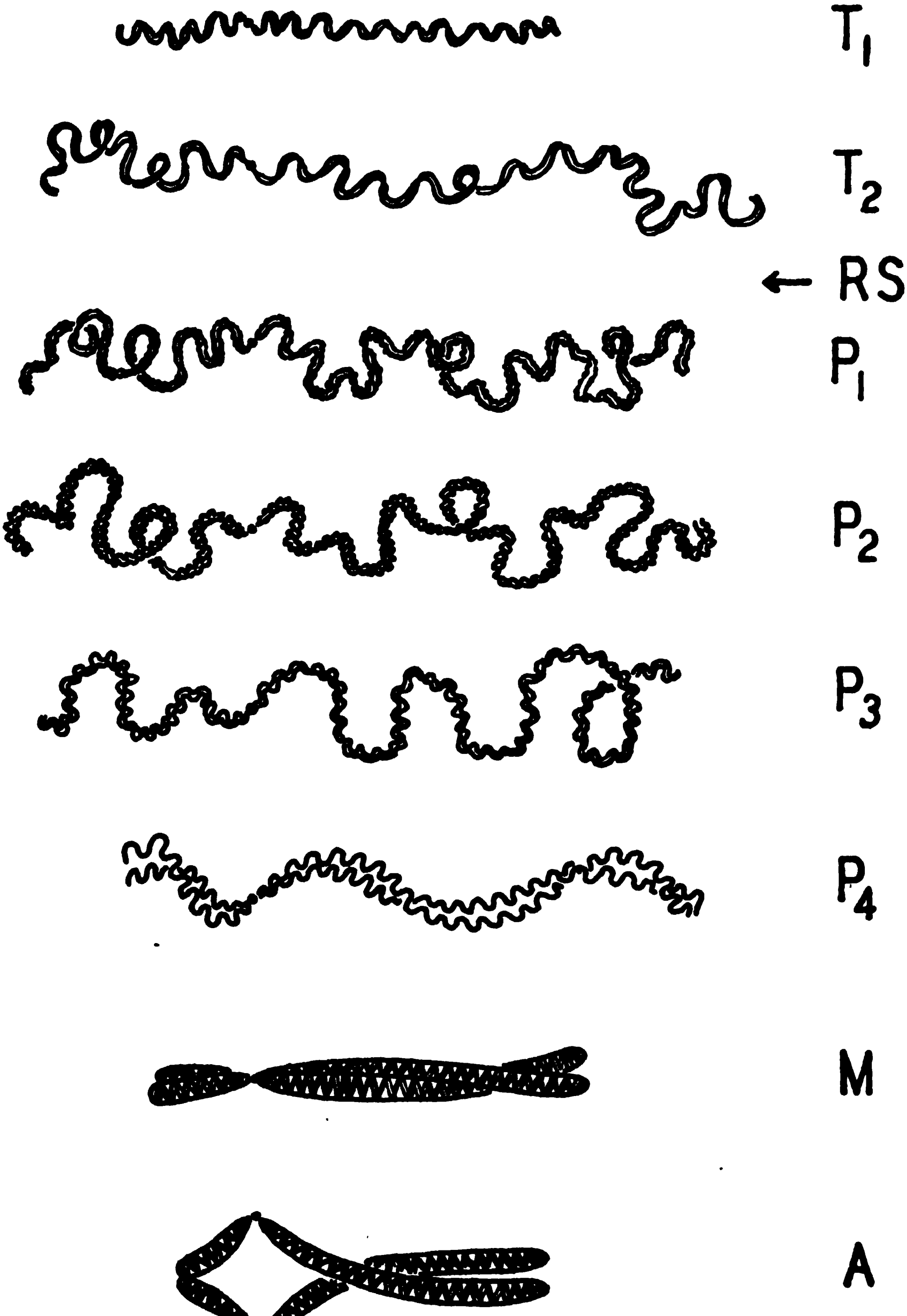


FIGURE 2. The spiralization cycle in a somatic chromosome of a non-dipterous insect starting from the telphase (T_1) of one mitosis and passing through the resting stage (RS unillustrated) to the anaphase (A) of the next. The somatic coils of the bipartite chromosome of T_1 become enlarged and, reappearing as relic coils in the next mitosis, are gradually resolved. At the same time the small undulations appearing in P_1 decrease in number and increase in size to constitute, by metaphase, the somatic coil. The relationally coiled chromatids which reproduce themselves during prophase become visibly bipartite by metaphase.

resolved. The tight packing of the chromonemata into somatic coils together with the nucleolar material accumulated on them causes them to appear by prometaphase as solid, rod-shaped bodies; they are then referred to as *chromatids*. Their true internal structure is usually demonstrable only following special methods of treatment.

Prometaphase

At the end of prophase, or by *prometaphase* as it is called, the chromosomes have reached their maximum contraction, the nuclear membrane disappears and the process of *spindle formation* occurs. This is a variable process but typically may be described as occurring in the following manner. As early as prophase, or even earlier, the two *centrosomes* lying close together and just outside the nuclear membrane start to move apart[8]. Having reached opposite sides of the nucleus by prometaphase, the centrosomes set up two poles and the nuclear membrane breaks down thus allowing the invasion of the nucleus by the contents of the cytoplasm. Under the action of the centrosomes the nucleo-cytoplasmic particles become orientated end-to-end and the aggregates so formed finally reach from pole to pole. These so-called fibres contain between them the more fluid portions of the nuclear sap. These more fluid interstices constitute "skids" along which the repulsion forces of the centromeres are able to act more freely. The chromosomes (paired chromatids) appear to be endowed also with a more general force of repulsion for they are dispersed more or less evenly throughout the cavity of the late prophase nucleus; maximum dispersion is reached by prometaphase. The mutually repellent forces of the chromosomes and especially of their single centromeres, on the one hand, and the two centrosomes, on the other, force the centromeres of the chromosomes to *congress*, or lie collectively, at metaphase, in an equatorial plate midway between the two poles. The centromeres then become associated with some of the fibres, which are then known as half-spindle components, while those uninterrupted by centromeres remain as continuous, or *primary*, fibres extending from pole to pole.

Metaphase

If the chromosomes are short, as in the Lepidoptera, the whole body of each chromosome of necessity lies flat on the metaphase plate. If long, as are some in the Orthoptera, they lie with their *distal* parts, i.e., the ends away from the centromere, projecting either out from the periphery, floating freely in the surrounding cytoplasm, or into the half-spindle masses on either side of the plate. As a general rule, where both large and small chromosomes occur together, as in the Heteroptera, the former assume a peripheral position, and the latter lie in the middle. Apart from this the members of the complement lie at random on the plate (except in the Diptera—see later). All these positions seem to point to a generalized repulsion keeping the chromosomes at a maximum distance from one another.

[8] The centriole (= centrosome) in viviparous snails has recently been shown by Pollister and Pollister (21) to be equivalent to a centromere, differing in behaviour in being isolated in the cytoplasm, while the latter lies within the nucleus as part of the chromosome. Moreover, it appears probable that centriole reproduction is from material derived from the centromeres which flows out from them along the half-spindle components. Hence the time of centriole reproduction seems to be limited to the time during which the spindle has its existence.

That the centromere is the main factor in the arrangement and movement of chromosomes is shown by the behaviour of chromosome fragments lacking a centromere (*acentric*) and other abnormal chromosomes possessing two (*dicentric*). The former fail both in normal congression and in normal anaphase movement[9]; the latter fail (in about half the cases) only in the anaphase separation of their chromatids, for the two centromeres of a daughter chromosome may as often move towards opposite poles as towards the same pole.

The position of the centromere is constant for each individual chromosome but may be different in different non-homologous chromosomes in the set. Thus chromosomes may be described as *mediocentric*, *telocentric* or *subtelocentric*. The position of the nucleolar constriction is invariable. It develops as a result of the inability of the chromosome to spiralize in that region where it was embedded in the nucleolus during prophase.

Only in the symmetrical field set up by the chromosomes congressing at the equator can the centromeres divide; this they do longitudinally by the time that the two chromatids have completed their reproduction of daughter chromatids. Thus in division the centromere is one whole cycle behind the chromosomes and almost one whole cycle behind the centrosome.

We have seen that (1) during the prophase the contents of the nucleolus have been distributed among the chromosomes; (2) during this distribution the chromosomes become progressively more stainable; and (3) with its completion the chromatids of each chromosome become visibly double. This splitting or division of the chromatids, as it is loosely called, involves not the longitudinal cleavage of the chromatid but the attraction and orientation by its particles of similar ones, so that one thread reproduces and becomes two. It is as though the nucleolus is the site for the storage during the resting stage of the excess material not used in the previous chromatid reproduction, together with additional material synthesized from the products of cellular metabolism. This material might then become transferred to and orientated by the molecules of the chromatids during the succeeding prophase, culminating in the reproduction of the daughter chromatids by metaphase. Hence, it seems, reproduction might be dependent on the association of nucleolar material with the chromatid thread. This is uncertain, but if true, reproduction cannot occur at the resting stage (*contra* Darlington, 9) but must have been occurring during the prophase of the previous mitosis[10].

Anaphase

The dual effect of the two new daughter chromatids, lying together and thus strongly repelling each other, together with the pairs of paired half-chromatids, releasing the attraction between single chromatids[11], moves the daughter chromosomes apart. The centromeres take the lead

[9] See footnote 11.

[10] Some authors are of the opinion that the chromosome at anaphase consists of one thread; others consider there are two or more. Reproduction according to the former authors occurs during the resting stage (since the chromosome is visibly double at the earliest prophase); opinions in the case of the latter group are variable. The unified theory of the writer is based on the chromatid as a single body and as the functional unit in pairing, chiasma formation and crossing-over, and in its mutational response to X-radiation.

[11] Carlson (4) has shown that daughter chromosome fragments devoid of centromeres and lying outside the spindle, though in the equatorial plane, can separate simultaneously with normal, unfragmented chromosomes; they lag, however, in later movement.

in this movement[12] so that a mediocentric daughter chromosome assumes the form of a V, with the apex pointed towards the pole, and a telocentric one the form of a rod, with the end at which the centromere is situated similarly pointed towards the pole. Where long and short chromosomes occur together, the daughter halves of the latter will be separated well in advance of those of the former; in the case of submediocentric chromosomes, the shorter arms will be separated before the longer arms.

The movement towards the poles is facilitated by the waning of the centrosome repulsions, perhaps due to a change in the nature of the substrate that adversely affects their repulsion, but more likely due to the centrosomes themselves undergoing reproduction in preparation for the following mitosis[13]. When the centromeres have travelled about two-thirds of the distance between the equator and the poles, autonomous movement ceases, and further movement is effected by the elongation of the middle region of the spindle lying between the two groups of separating centromeres (Belar, 1). This middle region, or *stem-body* as it is called, not only moves the two groups of daughter chromosomes apart, but the two poles also, so that the overall length of the spindle is greater at the end of anaphase than it was when originally formed.

Telophase

Due to the elongation of the spindle the two groups of chromosomes never quite reach the poles and consequently the centromeres in each group never become as closely aggregated as they would were this position attained. With the completion of the polar movement a new nuclear membrane is formed around each of the telophase groups and an incipient nucleolus appears. The chromosomes (paired chromatids) undergo initial "*de-spiralization*" and become progressively less stainable as they pass into the resting stage. The loss in stainability is completed by the resting stage[14]. The process of de-spiralization, however, is halted only temporarily: it restarts in the following prophase and is completed by mid-prophase. It consists not in a reversal or undoing of the spirals but, rather, in a continuation of the coiling which had its inception in the previous prophase. The spirals, at first large in number and small in diameter, gradually decrease in number and increase in size. At telophase this expansion is only about half completed, but by the following mid-prophase the number is reduced to a minimum and the size is increased to a maximum—hence the term relic coil.

There is no movement during the resting stage. At prophase the chromosomes are orientated, as they were at anaphase, with their centromeres against one side of the nuclear membrane and their arms radiating out towards the opposite side: they are polarized.

From this general account it will be seen that mitosis consists of a series of cyclical, co-ordinated changes and movements, both within and without the chromosomes, jointly concerned with the orderly separation of

[12] The centromeres at meiosis in *Sciara* (Metz, 19) and *Micromalthus* (Scott, 23) are exceptional in this regard.

[13] See footnote 8.

[14] Loss of stainability involves the return to the nucleolus of material earlier accumulated from it; generally, parts of the chromosomes or even whole chromosomes retain this material which then continues to stain deeply in the resting stage. Regions which show the normal cyclical staining properties are called *euchromatic*, those which do not are *heterochromatic* or *heteropycnotic*; the latter were originally known as *prochromosomes* and are often, if not always, genetically inert.

the daughter chromosomes. These involve (1) a lengthwise contraction of the chromosome by the development of a somatic coil, which appears to serve no end other than a convenience in mobility at metaphase congression and at anaphase separation; (2) the reproduction by metaphase of half-chromatids, attraction between which replaces the earlier attraction holding chromatids together; and (3) a co-ordination of the components of the substrate as an aid in the movement apart of the daughter chromosomes.

Somatic Pairing

The somatic chromosomes of the Diptera differ from those of all other insects, and, in fact, all other known organisms, in that throughout every mitosis the members of homologous pairs lie in close association with one another (Figure 3). Because of this there may appear to be only the *haploid* (single) number of chromosomes present rather than the *diploid* (double) number. The mechanical basis for this paired condition in the Diptera lies, at least in so far as can be seen, in that the chromosomes are single at anaphase[15]. The "division" of the body of the chromosome into daughter chromosomes and the centromere into daughter centromeres is synchronized, both being completed at the metaphase immediately preceding the anaphase in which daughters are to separate. At prophase the pairs of relationally coiled chromosomes differ in appearance from the pairs of relationally coiled chromatids in other forms only in that each has two centromeres, one the property of one chromosome, the other that of its homologue. By metaphase the relational coiling is completely resolved; also by this time each chromosome including the centromere has become double. The resolution of the relational coiling and the reproduction of the chromosomes allows the arms to separate, but the centric regions remain close together because of their anchorage to neighbouring half-spindle components. The derived centromeres of each chromosome then separate, moving daughter chromosomes to opposite poles, each closely paralleled by a daughter chromosome from a homologue.

So much for the manner in which the paired condition is maintained, but how does it originate? When the single set of chromsomes introduced by the male at fertilization lines up with that of the egg on the spindle of the first cleavage division, each chromosome of the double set has reproduced its arms and its centromere, and the daughter chromosomes separate to constitute the anaphase of this division. By virtue of the singleness of each anaphase chromosome, those of homologous pairs attract one another and re-establish the paired condition that was temporarily existing at metaphase (unpublished data). The paired chromosomes, lying closely parallel by telophase, undergo the resolution of their somatic coils and at the same time twist around one another (cf. Kaufmann, 15, Figure 56) to reappear at the succeeding prophase as relationally coiled pairs.

This phenomenon of somatic pairing may, in some Diptera, extend even into *meiosis*, i.e., those mitoses especially modified for the production of germ cells, and it is in all probability directly responsible for the occurrence of the giant, so-called *salivary gland chromosomes* peculiar to the Diptera.

[15] It is generally believed (following Kaufmann, 15) that the chromosomes of the Diptera are, like those of all other known organisms, double at prophase: their association in homologous pairs is, therefore, attributed to "a specially exaggerated property of attraction" (Darlington, 9). There is no unequivocal evidence for their doubleness and hence no demand for rationalization (Smith, 27).

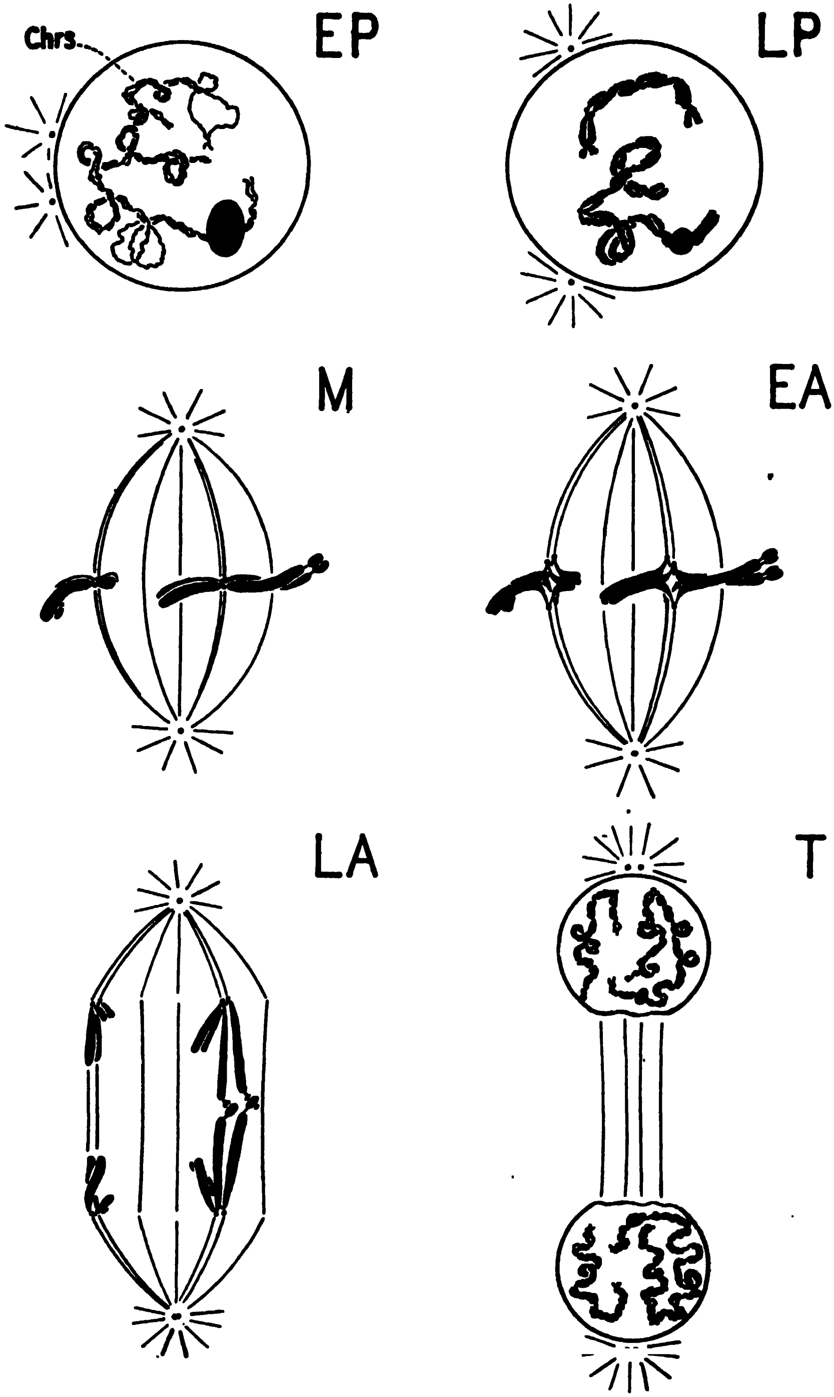


FIGURE 3. Mitosis in the Diptera: same stages as in Figure 1. At earliest prophase the chromosomes (Chrs) are single but homologous pairs are relationally coiled. By metaphase both reproduction of the chromosome and unwinding of the relational coil are completed. At anaphase single daughter chromosomes separate and homologues associate in pairs. They again become relationally coiled at telophase.

SALIVARY GLAND CHROMOSOMES

Within the nuclei of the secretory glands of the Diptera the chromosomes appear as enormously enlarged multiple threads present in the haploid number. They are almost certainly formed by the repeated reproduction of the paired (*contra* Koller, 17) chromosomes originally associated in the phenomenon of somatic pairing. The multiple threads, or *polytene* chromosomes, are transversely striated with bands of varying thickness which stain readily with ordinary nuclear dyes and which are separated by non-staining bands also of varying thickness. The polytene chromosomes are often fused together at their centromeres to form the *chromocentre* from which the nucleolus is suspended by a fine thread. Each band is actually a disc extending through the thickness of the polytene chromosome and made up of a number of granules, or *chromomeres*, each of which is joined by a fine filament to a granule in the disc on either side. Even in regions where the bundle of threads is separated into its two component groups, derived from the two homologous chromosomes, the similarity of the bands in the two is always exact, not only in a cell, but, apart from mutation, in all cells of individuals of the same species.

It would appear that these polytone chromosomes have arisen through the repeated reproduction of the somatically paired chromosomes unaccompanied by the compensating division of the cell[16], [17]: factors contributing to their remaining together are (1) the spindle has failed to form; (2) their prophase relational coiling has failed to become resolved; and (3) attraction in pairs is probably localised, exchanges of partners being possible as a result of the persistent relational coiling.

MEIOSIS

Meiosis and fertilization are antitheses. Fertilization consists in the union of two *gametes*, or germ-cells, in forming the *zygote*; meiosis consists in two divisions of the nucleus of the zygote accompanied by one division of its chromosomes in forming the gamete. Thus meiosis results in the chromosomes being numerically reduced to half the diploid number; fertilization results in the restoration of the double number.

Meiosis, then, is accomplished by two divisions of the nucleus, but the most distinguishing characteristics which differentiate it from mitosis are confined to the first of these divisions. The special characteristics of the process result solely from the chromosomes being single at the onset of the first division: they are not divided into chromatids. Their singleness arises from an anomaly in the mitosis immediately preceding meiosis, that is, in the last premeiotic division of the spermatogonia and oogonia[18]: the body of the chromosome, which throughout the earlier mitoses, has preceded the centromere in reproduction by a whole division cycle, at last loses this priority so that both are reproduced at the same time: synchrony in reproduction is achieved and, as we have seen in the Diptera, the conditions

[16] Goldschmidt and Kodani (10) have unorthodox views regarding the structure of polytene chromosomes.

[17] It should be noted that if chromosome reproduction entails the transfer of the contents of the nucleolus to the chromosomes, then there should be a rhythmic disappearance of the nucleolus synchronized with each reproduction. There is unfortunately no evidence on this point.

[18] Darlington, who considers the chromosome always to be single at anaphase with reproduction occurring at the resting stage, believes that meiotic prophase is precocious, occurring before the chromosomes have reproduced themselves: on this he bases his precocity theory of meiosis (Darlington, 6).

necessary for somatic pairing are established. When the daughter centromeres separate at anaphase, they disjoin not paired chromatids but single daughter chromosomes. The daughter chromosomes are thus in a condition strictly comparable to the daughter chromosomes at the anaphase of the first cleavage division in dipterous eggs. Moreover, their immediate reaction is comparable: homologous pairs are mutually attractive, an association is established, necessarily loose because of their spiral form, first in the centric regions and later sometimes in more distal regions, and, by unwinding their somatic coils, they proceed to coil relationally. In this state of greater or lesser association they pass into the resting stage.

The condition of the chromosomes at the earliest prophase of the first meiotic division is dependent upon the degree to which both the pairing and the relational coiling had progressed before the immobilization of the resting stage sets in. When first they become visible, at *leptotene*, they appear as long, thin, contorted, faintly-staining threads upon which are imposed numerous heavily-staining, bead-like chromomeres of various sizes (Figure 4). Although, on account of their length, it is rarely if ever directly demonstrable, these leptotene chromosomes are usually polarized with their centromeres towards the pole: this follows from their prior telophase orientation and the immobility of the resting stage. Each chromosome, *per se*, is single [19] but each is spatially in more or less close association with its homologue. This loose, *en masse*, pairing is then replaced by an intimate chromomere by chromomere pairing. This is the *synapsis*[20] of *zygotene*[21]. It commences primarily at the centromeres, since they lie closest—though it may be taken up secondarily by other homologous parts which also chance to lie closely enough together—and progresses outwards along the arms (Smith and Boothroyd, 28). With its completion the diploid complement of chromosomes is present as the haploid number of *bivalents*.

It is only now, at *pachytene* as it is called, that the reproduction of the chromosomes, omitted at the preceding metaphase, occurs; the object in this omission has been accomplished, the chromosomes are in pairs. As each chromosome of a bivalent becomes double, the attraction between its

[19] On the basis of the observable doubleness of the chromosomes at mitotic anaphase and telophase, some authors are loath to consider leptotene chromosomes as *single* pairing units; their direct evidence for doubleness at leptotene is questionable or absent. It is possible, however, that heterochromatic regions may be double.

[20] The anaphase-telophase of the last premeiotic division is thus the time of *conjugation* (as opposed to chromomere synapsis): here the chromosomes act as units in the same sense that *Paramoecia* are said to conjugate.

[21] Where doubleness is developed locally prior to zygotene no synapsis follows (Huskins and Smith, 11).

FIGURE 4. Meiosis in an insect that shows genetic crossing-over. Leptotene (L) showing single homologues with relic coils loosely associated in pairs and relationally coiled. Zygotene (Z) showing chromomere by chromomere pairing. Pachytene (P) showing pairing almost completed: the pairs are now 4-partite except at the centromeres. At early diplotene (ED) one chiasma (Xma) is visible in the shorter bivalent and three in the longer one; association otherwise is restricted to pairs of chromatids. During mid-diplotene (MD) the chiasmata move away from the centromeres and internal coiling is initiated. Diakinesis (Dia) showing complete terminalization of two of the chiasmata; maximum contraction is now reached. The first metaphase (MI) involves coorientation of the centromeres and anaphase (AI) shows the separation of the "homologous" chromosomes. Second metaphase (MII) and anaphase (AII) shows the orientation and separation of the internally double daughter chromosomes.

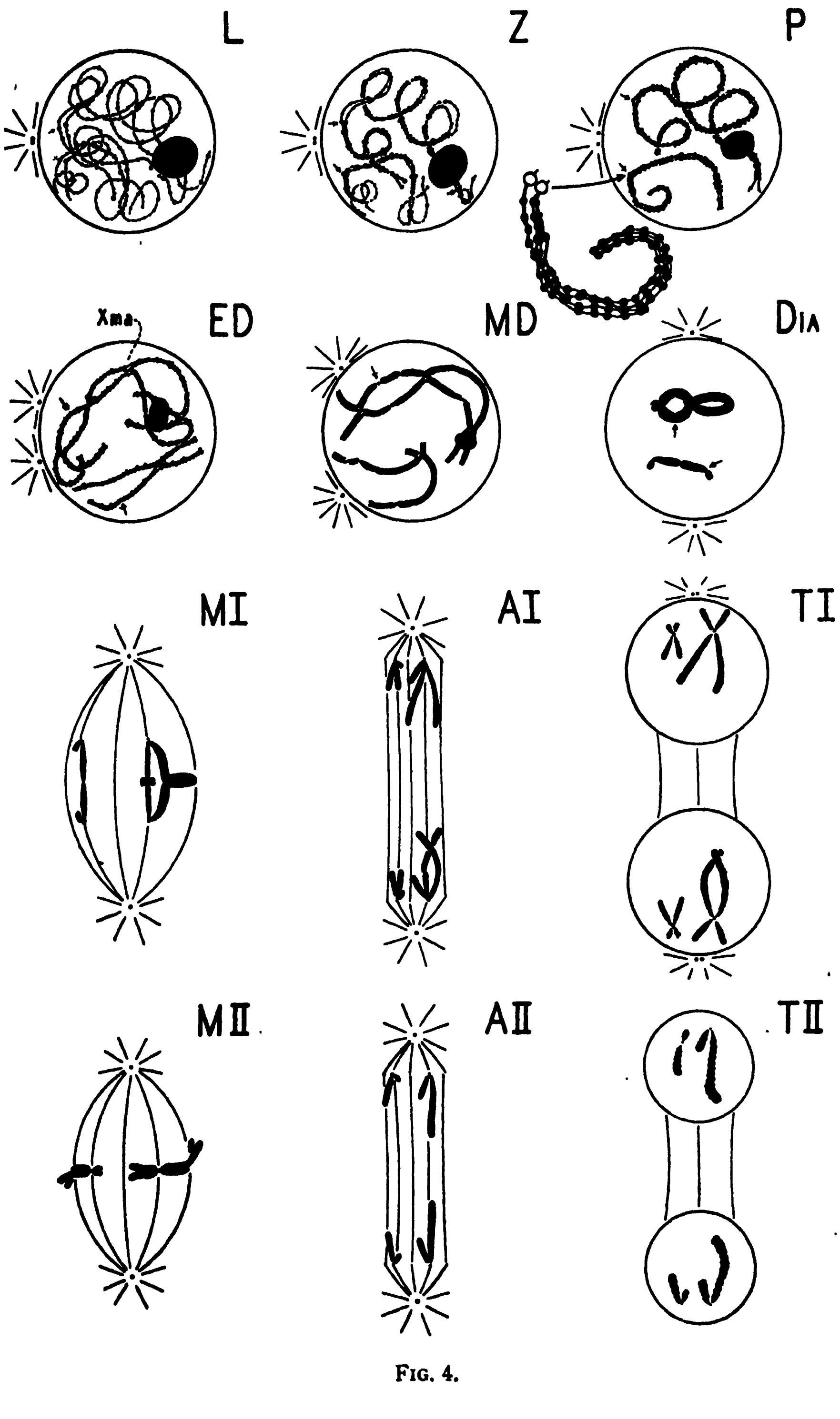


FIG. 4.

chromosomes lapses, for attraction is limited to pairs. The pairs of paired chromatids cannot separate completely, however, for it is seen that reciprocal exchanges have occurred between one thread of each pair; the two threads involved cross each other to form a *chiasma*. It is known that on either side of the chiasma those chromatids actually in paired association are the same ones as those originally formed at the delayed reproduction just mentioned (Darlington, 5). Hence the chiasma must be formed either by physical breakage of two homologous (not sister) chromatids followed by the criss-cross reunion of their broken ends (Darlington, 8), or by connecting fibres joining chromomeres of homologues at the reproduction of the chromatids at pachytene (Belling, 2). Which of these hypotheses, if either, is correct is unknown[22], but the chiasma, the end-result, is visible—it is the cytological manifestation of genetic crossing-over.

The pairs of paired chromatids move apart except, of course, where linked together by chiasmata. At this stage, *diplotene*, the bivalents, or *tetrads* as they are commonly called, if associated by one chiasma show the form of a cross, if by two, the region between them assumes the form of a circle.

As the diplotene stage progresses the chromosomes undergo spiralization, becoming broader and shorter, until, at *diakinesis*, they reach their maximum contraction and, because a general repulsion is still operative as at mitosis, they lie against the containing nuclear membrane more or less evenly dispersed; the nucleolus has already disappeared, the membrane dissolves, and the spindle of the first meiotic metaphase forms.

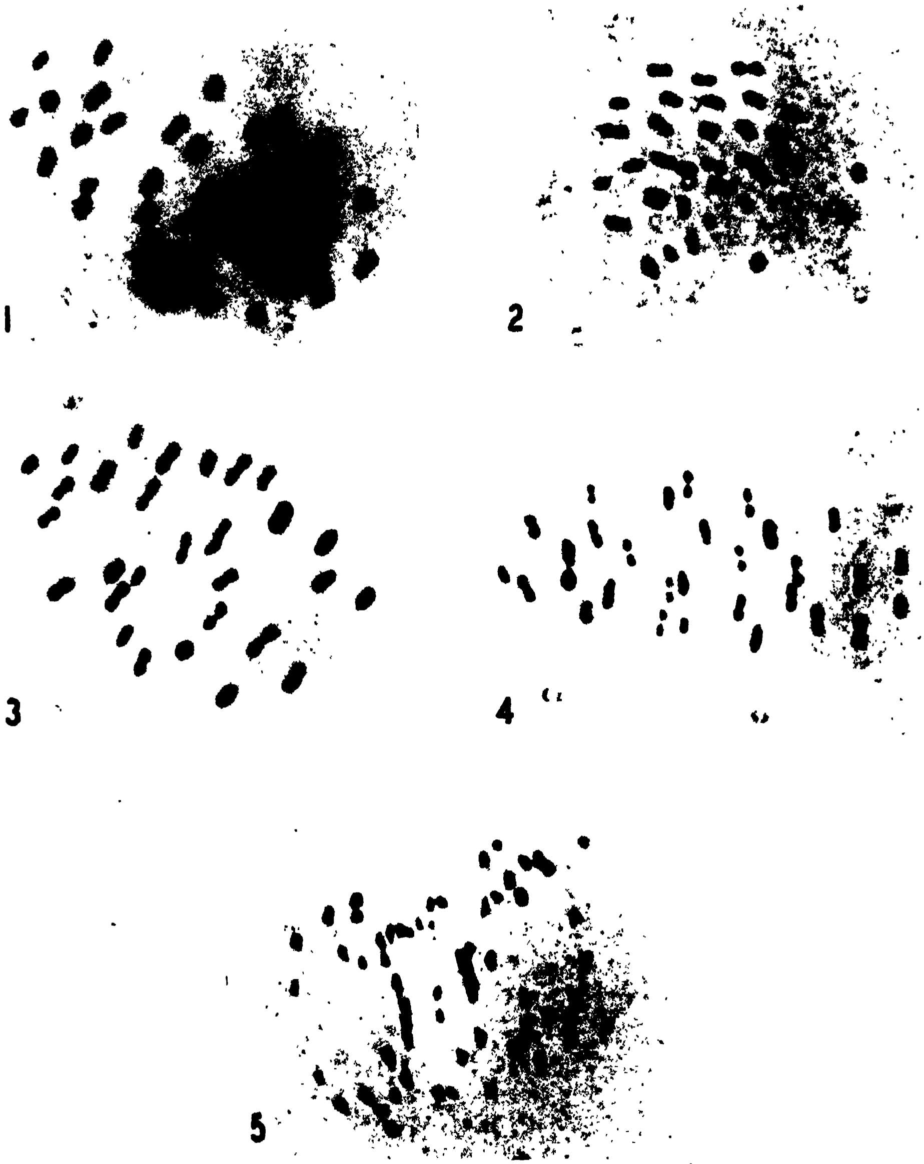
In the meantime certain changes of greater or lesser magnitude may have occurred in the disposition of the chiasmata. If the chromosomes are large, as are some in the Orthoptera, the metaphase positions of the chiasmata will be little or no different from that at their time of formation. If they are small, as is more generally the case with insects, the chiasmata *terminalize*, i.e., the crosses representing the genetic cross-overs move, by changes in association on either side, away from the centromeres[23]. If this terminalization is complete crosses become rods and tetrads with one or more chiasmata in each arm become simple rings[24]. In intermediate cases, where terminalization is incomplete, there may be only a shifting towards the ends, or where more than one chiasma is present in an arm, only the most distal chiasma may move to the end, the other or others moving a little but remaining interstitial. Whatever its degree of completeness, the association of the two segments containing the centromeres extends at the expense of the neighbouring segments not containing them: it is clear that terminalization is an aid in the separation to follow at anaphase.

The congression of the chromosomes on the equatorial plate at the first metaphase differs from that of mitotic chromosomes at the comparable stage. In the latter the centromeres lie in one plane on the equator and then divide. In meiosis the two pairs of chromatids composing the tetrad are each provided with a centromere and these are single and remain so until the metaphase of the second division. Instead of each lying on the

[22] Darlington (8) postulates torsion developed from a molecular coil as responsible for breakage.

[23] Mather (18) is of the opinion that terminalization is an all-or-none process.

[24] According to some authors a matrix (of extra-chromatic material?) is responsible for holding the chromosomes together following complete terminalization and in other instances where no visible connection is apparent.



EXPLANATION OF PLATES I-III

Photomicrographs taken from slides prepared by the squash method (Modified Kahle's fluid and leuco-basic fuchsin, Smith, 29).

PLATE I, 1-4. First metaphase of meiosis in male Lepidoptera. 1, *Zale* sp., 31 bivalents. 2, *Archips cerasivorana*, 30 bivalents. 3, *Archips* (*Cacoecia*) *fumiferana* from jackpine, 30 bivalents. 4, *A. fumiferana* from balsam, 30 bivalents. 5, First anaphase of meiosis in male *A. fumiferana* from balsam. Magnification = 2000.

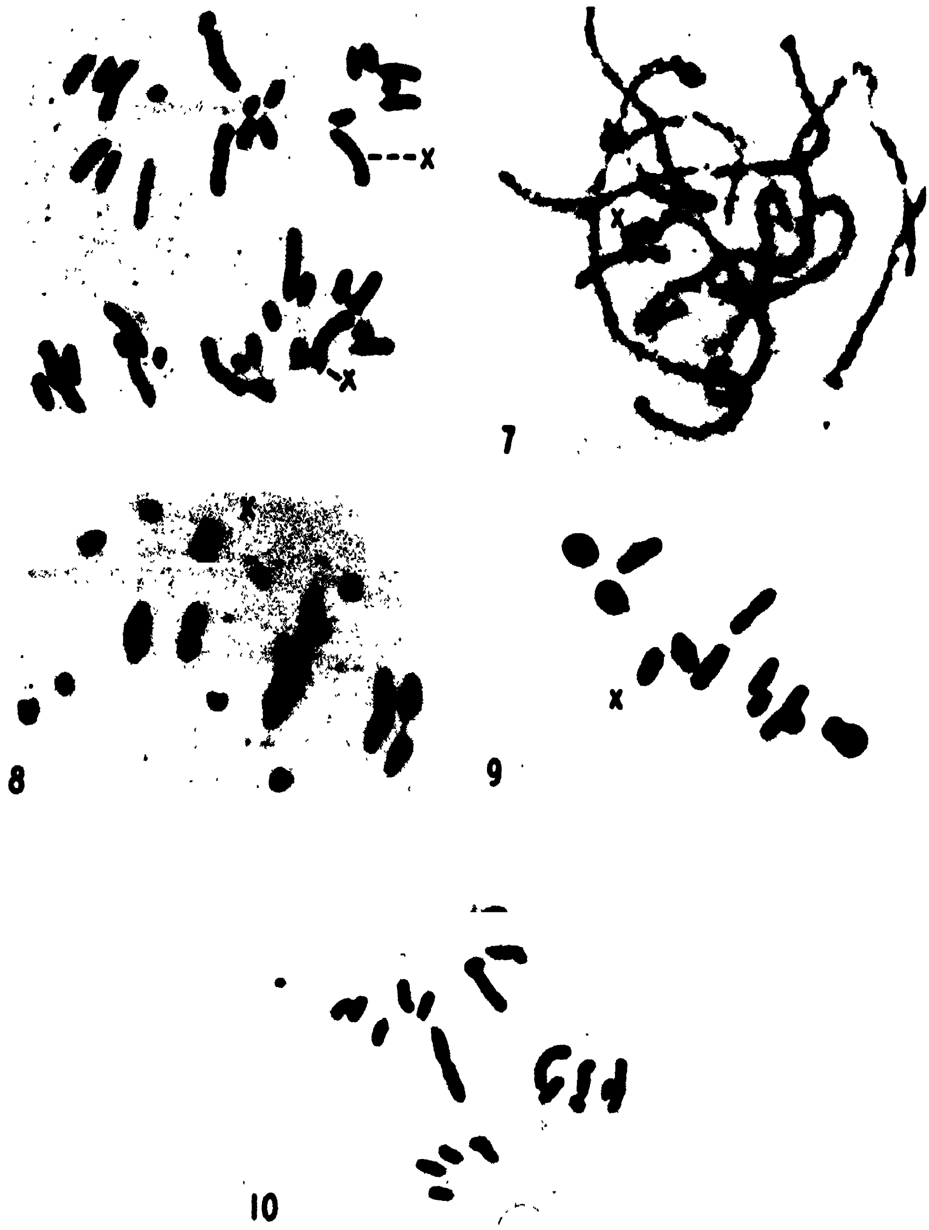


PLATE II, 6-10. Mitosis and meiosis in male of *Zubovskya* (*Podisma*) *glacialis canadensis* Walker (Acridiidae). 6, Spermatogonial mid-anaphase showing chromosomes conjugating in pairs prior to meiosis. 7, Pachytene showing the condensed X chromosome paired back on itself and heteropycnotic knobs on one end of each of the ten bivalents. 8, First metaphase of meiosis; ten bivalents plus the unpaired X chromosome. 9, First anaphase; five of the smaller bivalents have disjoined and the X chromosome has moved towards one pole. 10, Second anaphase in an X-containing daughter nucleus; the X chromosome has yet to complete division. N.B. the chromosomes in this species have terminal centromeres. Magnification = 1400.

PLATE III

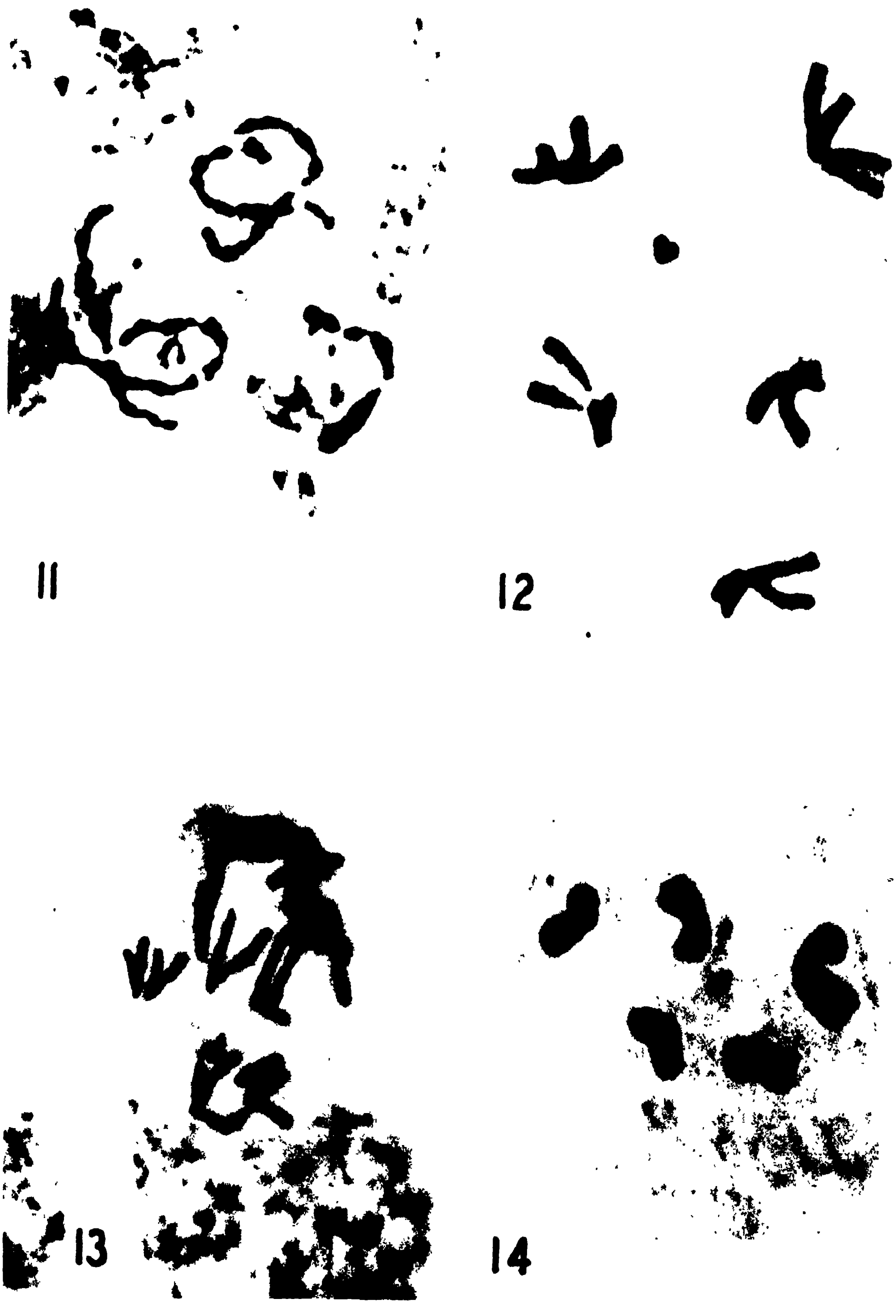


PLATE III, 11-14. Mitosis and meiosis in males of *Phorocera hamata* (Diptera). 11, Mitotic prophase showing somatic pairing; five "bivalents" plus a small XY pair. 12, Mitotic metaphase with non-coorientated centromeres. 13, Anaphase showing parallel association of daughter homologous chromosomes. 14, First metaphase of meiosis; the centromeres of the bivalents are coorientated, hence the XY pair looks single (the coorientation of one bivalent has been upset in squashing: it therefore resembles a mitotic pair). Magnification for 11, 12, 13 = 2000; for 14 = 3200.

equator, they arrange themselves symmetrically, one on either side of the equator. Ideally, then, it is the proximal chiasma that lies on the equator: the centromeres repel each other (as they did in terminalization) and become axially *co-orientated.*

Anaphase does not await the reproduction of the chromatids as it does in mitosis: there is no attraction to be overcome, the tetrad is already four-partite, a system of pairs repelling pairs. *Disjunction* commences with the attenuation of the regions between the centromere and the nearest chiasma, and the greater the number of unterminalized chiasmata, the greater the stretching. Finally, however, the pairs of paired chromatids separate, the two associated by a common centromere going to one pole, the other two to the second.

The dyads pass into the telophase which is followed by a very short resting stage, or *interphase* as it is called, and reappear in much the same condition at the prophase of the second division. Cytologically this division is mitotic in nature: as we shall see below, genetically it ensures the purity of the gametes. During prophase the centromeres and the body of the chromosome reproduce themselves, the chromosomes congress, and the daughter chromosomes (again internally double except in the Diptera) separate to form the nuclei of the gametes.

In those organisms in which there is no interphase and in which there is, therefore, no nucleolar-formation, the reproduction, above stated to occur during the second prophase, is accomplished between pachytene and metaphase of the first division. The chromosomes at the first anaphase are thus four-partite and arrive on the second division plate with no further reproduction.

The first important consequence of these two divisions is that the diploid number has been reduced to the haploid number which, owing to segregation, includes one member of each pair. Second, because the orientation of the pairs of centromeres is independent for each pair of chromosomes, random assortment of the chromosomes of each set has taken place. Third, these assorted chromosomes have undergone an alteration from their premeiotic constitution: homologous ones have exchanged parts, crossing-over has occurred. Now we see why the second division of meiosis is necessary: the numerical reduction is accomplished in the first division but the dyads are constituted of regionally dissimilar chromatids: they must themselves segregate at the second division. Hence we get four nuclei all different from one another and none exactly like either the paternal or the maternal half of the complement in the mother-cell. Meiosis thus introduces the maximum recombination of genetic differences. In the male the four nuclei all form sperm; in the female three are cast out of the egg and the fourth alone functions as the female pronucleus.

Fortuitous Univalents and Sex Chromosomes

Chiasmata are in general the prerequisites to an orderly chromosome reduction. In their absence, due either to mechanical difficulty in pairing or to chance failure, a bivalent will be represented by two *univalents*, i.e., the pair of chromosomes are *asynaptic*. The univalents may divide at either the first or the second anaphase or very infrequently at both, but

their products often fail to reach the telophase nuclei. Changes in chromosome number, either plus or minus, result, which, however, will rarely persist in future generations.

XO Sex Determination

Gametes with different chromosome numbers are, however, the normal products of meiosis in certain species of insects. These are those, like the majority of Orthoptera, in which the sex chromosomes are present twice in one sex (the female) and only once in the other. The non-sex chromosomes, or *autosomes*, are of course present in both sexes in duplicate. In the Orthoptera the single X of the male goes undivided (by an unknown mechanism) to one pole and its daughter halves disjoin at the second anaphase: two types of sperm in equal numbers are produced, the one with, the other without the X. In the female, on the other hand, the two X chromosomes behave as do the autosomes and all eggs come to possess the X chromosome. These may be fertilized by X sperm or by no-X sperm: the former give rise to female, the latter to male zygotes. The alternative condition in which the single X divides at the first anaphase and goes undivided to one pole at the second is the general rule in males of the Coreidae (Heteroptera): the end-result is identical.

Haplo-diploid Sex Determination

The extreme of the XO type of sex determination is met with in facultatively parthenogenetic Hymenoptera where males develop from unfertilized eggs and females from fertilized ones; the male is therefore haploid, the female diploid. All the chromosomes are, in a sense, sex chromosomes[25]. Meiosis in the female is again normal, but in the male, by virtue of the absence of homologues, pairing is impossible: all the chromosomes fail to divide at the first anaphase (although they have completed reproduction); instead they all move to one pole and the second division is purely mitotic. The mechanism governing this regular movement to one pole is unknown. All sperm produced by an individual therefore have the haploid number of chromosomes and all have the same genetic constitution. Prior to fertilization all eggs likewise have the haploid number of chromosomes—because normal meiotic reduction has been accomplished, but these may be genetically different—because crossing-over has occurred. If fertilized they will give rise to females, if unfertilized to males[26].

XY Sex Determination

The departure from normal meiosis is, with the exception of many Heteroptera, here less radical in that the behaviour of the sex chromosomes is fundamentally similar in both sexes to that of the autosomes. The X

[25] Whiting and his associates (see Whiting, 31) have clear evidence of multiple sex genes in the parasitic hymenopteran, *Habrobracon juglandis*: haplo-diploidy is therefore a secondary mechanism in this insect.

[26] The failure to form bivalents in the male hymenopteran would at first sight appear to be due to the absence of a second set of chromosomes. We find, however, that in those rare clusters of diploid spermatocytes that have arisen as the result of an early spermatogonial irregularity bivalents are likewise not formed (Smith, 26). There is no evidence why this is so, but it is conceivable that in haploid males there is no suppression of the last premeiotic reproduction which according to theory (Smith, 27) is essential to meiotic pairing. In the absence of homologues such a prerequisite to pairing would lose its significance; there would be no selection against a reversal to purely mitotic reproduction.

chromosome is present in duplicate in one sex; in the other it is accompanied by a chromosome, the so-called Y, which may differ from it morphologically as well as genetically[27]. With the exception of the Lepidoptera[28] and Trichoptera (Klingstedt, 16), it is the male insect which is *heterogametic*, i.e., capable of producing two types of gametes as regards the sex chromosomes. In these two orders the male is *homogametic*; it produces only X-containing sperm. In many pentatomids (Heteroptera) the X and Y chromosomes divide independently at the first division but come together at the second metaphase and then separate without further division: the end-result is similar in giving X and Y sperm in equal numbers.

Included in those forms having XY males is the Diptera. Dipterous males fall into two categories: those in which chiasmata are formed, as for example the Culicidae, Chironomidae, etc.; and those comprising all the higher forms (Brachycera) in which chiasmata and genetic crossing-over are absent. All show the phenomenon of somatic pairing and all females, but males of only the former type, have normal meiosis. Here the special timing lag by which reproduction and division occur together and which determines somatic pairing breaks down at the prophase of the first division of meiosis. The chromosomes, entering meiosis in the paired condition, complete their reproduction during the early prophase rather than at metaphase: crossing-over occurs and chiasmata hold the pairs of paired chromatids together until anaphase. In male Brachycera the reproduction-division cycle is undisturbed. The somatically paired chromosomes condense and spiralize before reproduction is completed and hence prohibit chiasma-formation. In one respect, however, the first anaphase separation in the Brachycera resembles that of other Diptera, rather than that seen in an ordinary dipterous mitosis. Separation is completely *reductional*, i.e., a whole paternal chromosome separates from a whole maternal homologue, whereas in mitosis the separation, as we have seen, is *equational*, i.e., one paternal and one maternal chromatid separate from a second paternal and a second maternal chromatid. Apparently at meiosis, whether chiasma-formation occurs or not, the spindle becomes operative before the centromeres can congress and divide: instead they co-orientate and disjoin.

CHEMISTRY OF THE NUCLEUS

In a paper dealing with the reproduction of the nucleus it would appear appropriate to devote some space to a consideration of the chemistry of the nucleus. The problems concerned with the submicroscopic structure of the nucleus, the types of protein and nucleic acids detected, and their distribution in and redistribution among the components of the nucleus have received considerable attention during the past few years (for review see Huskins, 12). We know that the chromosome is a fibrous protein, that when it stains with Feulgen's stain it is rich in desoxyribonucleic acid, that the nucleolus is the seat of ribonucleic acid (the two differing in the presence or absence of an oxygen atom), and that heteropycnotic chromosomes or regions retain their desoxyribonucleic acid when the remainder lose their staining capacity.

[27] In certain insects the situation is somewhat complicated by the X being represented by two or more separate chromosomes; the formula for the male is X^1X^2Y, etc.

[28] Certain Lepidoptera appear to have the formula ♂ = XX and ♀ = XY^1Y^2 or XO.

Details of the chemical processes involved in nuclear reproduction are still not understood (Mirsky, 20), but it is evident that this rapidly expanding field will in the future lead to a better understanding of the microscopic units with which we have been concerned.

SUMMARY

A brief account, largely of interest to entomologists only, is given synthesizing the fundamental features of mitosis and meiosis in insects. Chromosome reproduction during prophase is considered to be of universal occurrence. As a general rule the centromere lags behind the body of the chromosome in reproduction by one whole mitotic cycle; at anaphase the chromosomes (apart from their centromeres) are therefore double so that no attraction exists between them. The special case of somatic pairing in the Diptera is treated separately. Here synchronization in the reproduction of the body of the chromosome and its centromere results in single chromosomes after anaphase separation: homologous chromosomes therefore associate in pairs in each and every division. In insects other than the Diptera this synchrony is established only at or by the metaphase of the last gonial mitosis: homologues thus become conjugated, or associated in parallel, in preparation for the intimate pairing, or synapsis of zygotene. The key to the problem of meiotic chromosome pairing is therefore supplied by the Diptera: they constitute the connecting link between ordinary mitosis and meiosis.

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RIBOFLAVIN CONTENT OF MILK PRODUCTS FOR FEEDING PURPOSES[1]

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The use of buttermilk powder, and to a somewhat lesser extent, skim-milk powder, as a component of poultry and swine rations has been extremely widespread for a great many years. More recently, whey powder has also found some use in such rations. These dairy products have served, of course, as valuable protein supplements, supplying part of the animal protein desired in the rations. It was recognized very early that these materials contained other valuable nutritional factors, in addition to the protein. Of these factors, the best known and most intensively studied is riboflavin. Over a considerable period of years, it has been customary to recommend the inclusion of substantial amounts of the dried dairy by-products in poultry rations in order to supply the major portion of the riboflavin[5] requirements.

It is true that the depletion of supplies of milk products available for feeding purposes, together with the tremendously increased demand for poultry and swine production, has resulted, during these war years, in the use of many substitute or replacement materials to maintain the riboflavin levels necessary for high production. In many cases the deficit has been met by the prudent use of other natural feed stuffs, usually of lower potency, but quite frequently it has been necessary to fortify the rations by the use of pure crystalline riboflavin which is available from synthetic production. The milk products, nevertheless, are still very highly regarded and the inadequate supplies are in great demand. Furthermore, it is very probable that there will be some considerable return to the use of these products as they become increasingly available again in the future. Hence it appears that the presentation of the accompanying information which was gathered two or three years ago, should be of interest and value at the present time to both the purchasers of feedstuffs and the processors of dairy products.

The development of assay methods for riboflavin, first of all by biological means but more particularly by the simpler fluorometric and microbiological procedures, has resulted in extensive analyses of the riboflavin content of various types of feeding materials. The literature of the past few years contains numerous reports of such analyses, usually, however, on small numbers of samples of any one type of material, or on

[1] A contribution from the Department of Biochemistry, Ontario Research Foundation, Toronto, and the Department of Animal Nutrition, Ontario Agricultural College, Guelph. The majority of the assays were conducted in the laboratories of the Ontario Research Foundation.

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[5] In the earlier years it was the practice to speak of Vitamin G or Vitamin B_2, whereas the chemical name, riboflavin, is now used for the same factor.

special products involved in specific feeding-trials or investigations. Reports by Culton and Bird (2) and by Hodson and Norris (4) are among those which cover somewhat more extensive studies of the riboflavin content of feedstuffs. The former authors reported a range of 17.6 to 29.4 micrograms per gram in 13 samples of dried skimmilk, 12.4 to 29.7 in 5 samples of dried whey, and 31.5 to 39.0 in 10 samples of dried buttermilk. In addition, they found no significant seasonal variation in the riboflavin content of dried skimmilk and buttermilk. Hodson and Norris found a lesser degree of variation in 5 samples of dried skimmilk and 5 samples of dried whey. Most published tables of vitamin values express the content of riboflavin and the other vitamins as "average" values, that is, the average of the large number of values recorded in the literature. Examples of such tables of average vitamin values are those presented by Titus (6) and Ewing (3), and others are to be found in most text books and reviews dealing with animal nutrition. Such values are, at best, valuable only as indications of possible nutritive importance, and, if not used with discretion, may be quite misleading in many cases. If rations are composed on the basis of "average" values, two possible eventualities can be visualized, namely, the wasting of the riboflavin carrier if its potency is in excess of that average figure, or a riboflavin shortage in the ration if the potency of the carrier is below the average. Less frequently encountered are tables which record the observed range of vitamin values for feedstuffs. One example of this type is the table published by Almquist (1), in which the following ranges of values, in micrograms of riboflavin per gram, are recorded: Dried buttermilk 27.3 - 37.8, dried skimmilk 16.1 - 32.4, dried whey 16.2 - 40.0.

Little information has been published on the riboflavin values of milk feedstuffs available in Canada. The work reported here was undertaken in an attempt to remedy this situation and to study the variations in riboflavin potency of products from different plants and from the same plant at different times.

EXPERIMENTAL

In nearly all cases the samples of dried buttermilk, dried skimmilk and dried whey were obtained directly from the producers. In most of the cases in which the samples were obtained from distributors, information on the initial source was furnished with the samples. Most of the samples were from Ontario processing plants, a few were from Quebec plants and only a very few originated elsewhere. Three samples of whey powder and one of skimmilk powder came from United States production which was being marketed in Canada. The majority of sources were represented by single samples, but a number of producers furnished two, three or more samples.

The actual assays of the samples were carried out by a modification of the Snell and Strong (5) microbiological method, in which the extracts were prepared by autoclaving the samples with one-tenth normal hydrochloric acid solution. Subsequent changes in the microbiological procedure have not markedly influenced this laboratory's results on materials of this type, so that the absolute results should compare favourably with those obtained by the more recent procedures. In any event, since the same method was used for all samples covered herein, the relationship of the

values obtained is reliable. Repeat microbiological determinations and assays by a fluorometric method were conducted on a considerable number of the samples and in all cases results agreed closely with the figures from the original microbiological assays, providing further evidence of the reliability of these determinations.

RESULTS

The riboflavin potencies found for the individual samples, together with some information on the samples, are presented in Tables 1, 2, and 3. For purposes of this report, the sources are identified by numbers. These tables require little explanation. It should be pointed out that the results for skimmilk samples 2 and 242 suggest the possibility of an incorrect labelling of these samples at the source, since the values are more typical of the range for buttermilk powder than for skimmilk powder.

TABLE 1.—RESULTS OF ASSAYS OF BUTTERMILK POWDER SAMPLES

Sample no.	Source no.	Date received	When processed	Riboflavin content (Micrograms per gram)
79	3	Feb. 6/41	—	20
121	5	Mar. 8/41	—	33
86	5	Mar. 14/41	Feb./40	32
3	6	Dec. 13/40	—	41
93	6	Jan. 17/41	Dec./40	36
99	6	Mar. 1/41	Jan./40	31
4	7	Dec. 13/40	—	33
72	7	Jan. 17/41	Dec./40 (A)	41
94	7	Jan. 17/41	Dec./40 (B)	27
95	7	Jan. 17/41	Summer/40	22
218	7	May 15/41	Mar./41	34
80	11	Feb. 6/41	—	23
52	16	Jan. 9/41	—	32
50	17	Jan. 9/41	—	48
111	18	Mar. 8/41	—	38
54	20	Jan. 9/41	—	29
82	21	Mar. 1/41	Feb. 15/41	33
81	21	Mar. 1/41	Feb. 20/41	37
57	24	Jan. 9/41	—	39
48	25	Jan. 9/41	—	41
56	26	Jan. 9/41	—	39
96	26	Jan. 17/41	—	27
1	30*	Dec. 5/40	—	41
36	30	Dec. 13/40	—	40
70	30	Jan. 17/41	—	36
71	30	Jan. 17/41	—	33
87	30	Mar. 14/41	—	34
216	30	May 15/41	—	29
238	30	May 15/41	—	34
247	30	June 11/41	—	28
248	30	June 11/41	—	32
259	30	June 11/41	—	30
275	30	July 3/41	—	31
277	30	July 8/41	—	28
278	30	July 8/41	—	23
13	33	Dec. 13/40	—	20
B 6	40	Dec. 13/40	—	45
6	41	Nov. 28/40	—	43
92	41	Jan. 9/41	Dec./40	34
88	41	Mar. 14/41	—	42

TABLE 1.—RESULTS OF ASSAYS OF BUTTERMILK POWDER SAMPLES—*Concluded*

Sample no.	Source no.	Date received	When processed	Riboflavin content (Micrograms per gram)
113	41	April 30/41	Mar. 31/41	32
217	41	May 15/41	April/41	37
258	41	June 11/40	May/41	38
E 5A	41	Sept. 18/41	Aug./41	39
E 9A	41	Oct. 18/41	Sept./41	40
E 18A	41	Nov. 18/41	Oct./41	30
E 29	41	Dec. 18/41	Nov./41	45
E 33	41	Jan. 20/42	Dec./41	45
E 35	41	Feb. 19/42	Jan./42	40
E 40	41	Mar. 23/42	Feb./42	47
49	43	Jan. 9/41	—	26
55	45	Jan. 9/41	—	43
47	49	Jan. 9/41	—	38
E 65	54	June 22/42	—	48
97	55	Feb. 6/41	—	26
B 1	?	June 30/39	—	38
78	?	Feb. 6/41	—	41
276	?	July 3/41	—	31

Range of values: 20 - 48
Distribution: 13 samples 20 - 29
28 samples 30 - 39
17 samples 40 - 48

* The source designated as number 30 was not a producer, and definite information as to the producer was not available. More than one producer may be represented.

The range of riboflavin potencies was quite wide in each of the three types of material. The greatest range was found in the case of buttermilk powder. The distribution of the values for buttermilk powder, shown in Table 1, indicates that the wide range of potencies cannot be attributed merely to one or two samples which deviated from the average. The validity of the range for whey powder is less well established since the number of samples involved was not very large.

In Table 4 is assembled the potency information for all instances in which two or more samples were received from the same producer. It is evident that, in many cases, marked variation in riboflavin potency is encountered in the materials from a single producer.

The limited information available on the processing dates and the type of process employed does not permit of any conclusions on possible variations with season or with processing methods.

Further intensive studies to ascertain and, if possible, overcome, the causes of these wide variations should be of practical importance to both the producers and consumers of milk feeds and such studies are contemplated.

SUMMARY

Fifty-eight samples of buttermilk powder, 35 samples of skimmilk powder, and 9 samples of whey powder were assayed for riboflavin content by the microbiological method. All samples represented feeding materials commercially available in Ontario.

TABLE 2.—RESULTS OF ASSAYS OF SKIMMILK POWDER SAMPLES

Sample no.	Source no.	Date received	Riboflavin content (Micrograms per gram)
101	2	Mar. 8/41	18
75	3	Feb. 6/41	19
66	4	Jan. 17/41	19 (R)*
59	4	Jan. 17/41	17 (R)
63	4	Jan. 17/41	20 (S)
64	4	Jan. 17/41	18 (S)
106	5	Mar. 8/41	16
85	5	Mar. 14/41	16
2	6	Dec. 13/40	40
62	6	Jan. 17/41	19
242	6	May 15/41	38
60	7	Jan. 17/41	19
61	7	Jan. 17/41	20
39	10	Jan. 9/41	19 (R)
76	11	Feb. 6/41	24
45	14	Jan. 9/41	21
40	15	Jan. 9/41	18 (R)
42	17	Jan. 9/41	20 (R)
44	17	Jan. 9/41	21 (S)
125	18	Mar. 8/41	23 (S)
126	18	Mar. 8/41	19 (R)
41	19	Jan. 9/41	17 (S)
43	20	Jan. 9/41	16 (R)
51	25	Jan. 9/41	19 (R)
38	27	Jan. 9/41	19
15	33	Dec. 13/40	21
68	34	Jan. 17/41	21
77	35	Feb. 6/41	18
53	43	Jan. 9/41	20 (R)
33	47	Dec. 13/40	21
37	49	Jan. 9/41	13
74	55	Feb. 6/41	16
279	?	July 8/41	17
280	?	July 8/41	17
281	?	July 8/41	16

Range of values (omitting samples 2 and 242): 13 – 23.

*Letter in bracket designates processing method: R—Roller, S—Spray.

TABLE 3.—RESULTS OF ASSAYS OF WHEY POWDER SAMPLES

Sample no.	Source no.	Date received	Riboflavin content (Micrograms per gram)
46	39	Jan. 9/41	14
65	39	Jan. 17/41	16
67	39	Jan. 17/41	16
E34	52	Jan. 26/42	27
E54	52	Mar. 5/42	20
E55	52	Mar. 5/42	22
E45	56	May 11/42	24
E46	56	May 11/42	22
E50	57	May 17/42	20

Range of values: 14 – 27

TABLE 4.—VARIATIONS IN DRIED MILK PRODUCTS FROM SAME PRODUCER

Product	Producer	Number of samples	Range of riboflavin values (Micrograms per gram)
Buttermilk powder	6	3	31 - 41
	7	5	22 - 41
	21	2	33 - 37
	41	13	30 - 47
Skimmilk powder	4	4	17 - 21
	5	2	16
	6	3	19 - 40*
	7	2	19 - 20
	17	2	20 - 21
	18	2	19 - 23
Whey Powder	39	3	14 - 16
	52	3	20 - 27
	56	2	22 - 24

* See note in text regarding samples 2 and 242.

Wide variations in the riboflavin content of similar products were found. In many cases, similar products from a single producer showed marked variations in riboflavin potency.

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The authors wish to express their thanks to the many producers and distributors for their kind co-operation in making available the samples of dried milk products involved in this survey.

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THE YIELD AND OTHER CHARACTERS OF INBRED LINES AND SINGLE CROSSES OF SUNFLOWERS

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The original selections of sunflowers secured by the Dominion Forage Crops Laboratory consisted of a great variety of types, and their progenies were very variable. In the attempt to secure homzygosity for such characters as high oil content, non-branching, low hull percentage, etc., inbreeding was practised. It was soon evident that while the objective of increased uniformity was being attained, vigour was being sacrificed. Hybrids between inbred lines produced by hand pollination appeared so promising that as the next step a procedure similar to the hybrid corn technique was utilized for producing single crosses on a fairly extensive scale. It is the purpose of this paper to report the results of inbreeding and of preliminary studies with hybrids.

LITERATURE REVIEW

The utilization of the hybrid corn technique for increasing sunflower seed yields was suggested in Russia as early as 1934 by Morozov (4). He used isolation plots for natural crossing of inbred lines and obtained crossing of from 15.6 to 77.8%. He reported increases in seed yield of up to 22% over the original parental varieties.

Jagodkin (2), another Russian worker, reported obtaining lines pure breeding for disease and insect resistance, strong single stems, high oil content, and other characters as a result of selective inbreeding. By hybridization of these resistant lines he obtained seed yields above those of standard varieties. He also suggested the utilization of the hybrid corn technique to increase commercial yields of this crop.

The effect of inbreeding and crossing sunflowers is similar to that experienced with other naturally cross pollinated crops. Kirk (3) and later Tysdal *et al.* (7) showed that marked reductions in forage and seed yields followed the inbreeding of alfalfa. The latter reported significant increases of both forage and seed yields in F_1 hybrids compared to standard varieties. Hayes and Schmid (1) reported that the F_1 of crosses between inbred lines of brome-grass yielded 126.5 to 220.9% of the commercial check. Although having a direct bearing on the problems of producing hybrid sunflowers, the literature dealing with hybrid corn is too extensive to review here.

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MATERIALS AND METHODS

Inbreeding Study

Of 207 lines obtained from open fertilized single head selections made from unimproved Mennonite material in 1937, because of the presence of undesirable characters or the lack of sufficient self-fertility, all but 4 lines had been discarded by 1942. In the case of only 2 of these 4 lines was there sufficient reserve seed of the original selection and each of 4 subsequent inbred generations to enable the laying down of a triple rod row plot with 3 replicates. A split plot design was used in which the 2 strains constituted the main plots and the different generations the sub-plots. Reserve selfed seed of plants selfed in each generation was bulked to represent that generation of the line. Rows were spaced 3 feet apart with plants in the rows being from 5 to 8 inches apart, this spacing being recommended for commercial production (6). Seeding was done with the Columbia seeder to a depth of about 2 inches. Unless otherwise stated, the seeding and thinning after emergence was done as is described by Putt and Unrau (6).

Crossing Study

In 1940, two plants in 1 line inbred for 3 generations were reciprocally crossed with 2 plants from another line having like inbreeding history. Crossing was done without emasculation, pollination being performed periodically until flowering on each head was complete. Enough crossed seed was obtained from each of the 2 lines for a single rod row, 6 replicate test in 1941. In 1941 these same lines were hand crossed but in addition an isolated plot was set out in which the 2 lines were sown in alternate rows and allowed to cross naturally. The seed from the natural crossing plot was used to establish a test at both Saskatoon and the Dominion Experimental Station at Swift Current in 1942.

In 1942 isolated plots were set out involving in pairs various combinations of Sunrise and 3 inbred lines of Mennonite. Some of these were unsuccessful since flowering did not occur simultaneously. A successful plot was, however, obtained for the 2 lines used in the 2 previous years. In 1943 tests were conducted involving this and other crosses. In all tests data were obtained on the yield of seed calculated in pounds per acre. Measurements on plant height and head diameters were taken at maturity on 5 random plants in each plot, the average of these separate measurements being used as the plot value. Seed size as indicated by 1000 kernel weight was measured by weighing three lots of 100 seeds from each plot. Weight per bushel was obtained when sufficient seed was available. Percentage kernel to hull was obtained in the years 1941 and 1942 by hand separation on a 5-gram sample from every plot. In 1943 this determination was made with a mechanical huller using a 10-gram sample per plot.

Oil analysis, based on the dry weight of the whole seed, was obtained on a composite sample made up from seed from each replicate of a treatment. The determinations were made by the Oil Seeds Laboratory, University of Saskatchewan, Saskatoon.

RESULTS AND DISCUSSION

Inbreeding Study

A summary of the data from the inbreeding study conducted in 1942 is presented in Table 1.

TABLE 1.—INFLUENCE OF FOUR CONSECUTIVE GENERATIONS OF INBREEDING ON THE YIELD OF SEED AND OTHER CHARACTERS IN TWO LINES OF SUNFLOWERS

(A = S-37-$\overline{25}$, B = S-37-$\overline{49}$)

Generation of inbreeding	Yield per acre			Plant height			Head diameter			100 seed wt.	
	Line A	Line B	Av. 2 lines	Line A	Line B	Av. 2 lines	Line A	Line B	Av. 2 lines	Line A	Line B
	lb.	lb.	lb.	in.	in.	in.	in.	in.	in.	gm.	gm.
Orig. open	2187	2030	2108	53.7	55.0	54.4	8.3	8.4	8.4	77	73
1st	1777	940	1358	50.0	47.7	48.8	8.0	6.8	7.4	78	65
2nd	1037	1190	1114	45.3	44.0	44.6	6.6	6.9	6.8	87	64
3rd	1057	993	1025	46.3	40.3	43.3	6.3	7.4	6.8	71	56
4th	797	877	837	44.3	47.7	46.0	6.0	6.8	6.4	71	52
Line Av.	1371	1206		47.9	46.9		7.0	7.2		76.8	62.0
L.S.D.* between generations between 5% point			365			5.4			.47		
generations 1% point			502			7.4			.65		

* Least Significant Difference.

The most significant effect of inbreeding on vigour is indicated in the data for seed yield. As an average of both lines a reduction in yield amounting to 35.6% and exceeding odds of 99 : 1 for significance resulted from 1 generation of inbreeding. Four generations of selfing decreased the yield by 60.3% as an average of both lines. The reduction in yield was much less in the later generations of inbreeding, there actually being a significant difference only between the fourth and the first generation. This levelling off of the loss in yield in later generations is to be expected if it is assumed that yield and vigour are proportional to the heterogeneity of the material.

Analyses of variance showed a significant interaction of lines × generations. It is obvious from the Table 1 that while the decline in yield of the 2 lines is similar from the second generations onward, Line B showed a much greater drop than Line A as the result of the first generation of inbreeding.

Significant effects of inbreeding are noted also in the data for plant height and head diameter. These characteristics give an indication of plant vigour, and it is evident that for both characters there is a reduction exceeding the 1% point for significance as the result of 4 generations of inbreeding. Again the greatest reduction occurs in the early generations and there is also a levelling off tendency in the later generations. As in the case of yield, Line B had a greater drop in the first generation in height and head size than Line B.

Since small seed size is considered desirable, the effect of selection on seed size is of interest. Line A is large seeded and highly self-sterile. It appeared that only the large seeded plants gave sufficient seed to carry on the line. Therefore seed size is fairly similar in all generations. Line B, on the other hand, was fairly self-fertile and selection for small seed size

was possible, with the result that there was a more or less progressive decrease in size with each advance in generation of inbreeding.

The later inbred generations within a line were highly uniform in plant type, stem strength, head shape, seed colour and other visible characteristics. At the same time between lines there were some fairly obvious differences of visible characters. An indication of the variability in the original open pollinated selection as contrasted to the relative uniformity of the fourth generation inbred progeny of that selection may be seen in Figure 1.

FIGURE 1. Comparison of open fertilized selection (on left) and 4th generation inbred of the same line (on right). Note variability in plant height and stem strength of open fertilized row as contrasted to the uniformity for those characters in the inbred, which was also uniform for head shape, pigmentation of leaves, flowers and seeds.

Crossing Studies

The F_1's of 2 inbred lines crossed reciprocally by hand without emasculation in 1940, were tested in comparison with the inbred parents in 1941. A summary of the data from this test is presented in Table 2.

The most significant feature of the data in Table 2 is the high seed yield of the single crosses. As an average the reciprocal crosses yielded 247% of the average of the inbred parents. Unfortunately no Mennonite material was included in this test as a check, but the average yield of Mennonite grown under similar conditions in an adjacent 6 replicate test was 830 pounds per acre. The single crosses, therefore, yielded 60.8% more than the Mennonite variety in this adjacent test.

With respect to other characters, the effect of hybrid vigour is clearly seen in the significantly greater height, head diameter, and seed size of the single crosses compared to the parent inbreds. Percentage kernel was

somewhat lower in the F_1's. It should be pointed out that while the values for seed size were higher for the hybrids than for the inbred lines, this was largely due to the poor seed development of the inbreds and the more normal seed development of the single crosses. With regard to percentage oil the hybrids, while a little lower than their parents, were higher in oil than any Mennonite or Sunrise material in that year, indicating that obtaining a combination of high seed yield coupled with high oil percentage is possible. In this test there were no actual counts made to determine the proportion of selfs to hybrids, but very few selfs were observed in the hybrid rows.

TABLE 2.—COMPARISON OF YIELD AND OTHER CHARACTERS OF TWO PARENT INBRED LINES AND THEIR RECIPROCAL SINGLE CROSSES PRODUCED BY HAND POLLINATION

Material	Yield per acre	Height	Head diam.	1000 seed wt.	Percentage kernel	Percentage oil
	lb.	in.	in.	gm.	%	%
Inbred Line B*	543	31.2	3.1	27.4	73.3	36.9
Inbred line C†	539	39.8	3.9	24.7	65.6	36.4
F_1 B × C	1320	44.5	4.9	47.9	64.9	35.6
F_1 C × B	1349	41.4	5.3	46.7	64.5	34.5
Nec. diff. odds 19 ÷ 1	564	3.0	0.9	15.8	5.8	

* = Line S-37-49. † = S-37-388.

In 1941, Lines B and C were put in an isolated natural crossing plot. The determination of the degree of natural crossing was possible because Line B carries a factor, or factors, for purple seed coat colour the expression of which is inhibited when selfed but which on crossing is expressed irrespective of the direction of the cross. In 1942 the percentage of hybrids was found to be 57.6 in the single cross of B X C and 80.8 in the single cross of C × B. Both inbred lines are about equally self fertile, but Line B is a heavier pollen producer than Line C which fact may account for the difference noted above.

Data on the yield and other characters of single crosses in tests at Saskatoon and Swift Current are presented in Table 3.

As in the previous year's test the single crosses were very significantly superior in yield as compared to the inbred parents. In addition they greatly outyielded the Mennonite and Sunrise checks. The comparatively high yield of inbred Line B is somewhat puzzling, but it may be that the season was especially favourable for the development of this line. On comparing the 2 single crosses it appears that yield bears some relationship to the extent of natural crossing. The F_1 of C × B with 80.8% crossing significantly outyielded the F_1 of B × C in which only 57.6% crossing occurred. At the same time it should be pointed out that the single cross of B × C outyielded by odds in excess of 99 : 1 both of the inbreds and the 2 varieties, the actual increase over Mennonite being 47.4%. With respect to the other characters heterosis is again evident in the greater

TABLE 3.—AVERAGES FOR YIELD AND OTHER CHARACTERS OF SINGLE CROSSES PRODUCED BY NATURAL CROSSING AND TESTED AT SASKATOON AND SWIFT CURRENT, 1942

Material	Yield per acre	Plant height	Head diameter	1000 seed wt.	Weight per bushel	Percentage kernel	Percentage oil
	lb.	in.	in.	gm.	lb.	%	%
Mennonite	998	55.5	4.8	60.1	26.6	53.4	29.2
Sunrise	361	50.8	4.8	27.9	22.2	53.9	25.4*
Inbred B	1177	48.6	5.2	46.0	25.5	60.0	31.0
Inbred C	351	43.2	4.2	30.0	21.5	63.0	32.2
F_1 B × C	1471	56.4	5.8	60.2	27.4	56.6	30.6
F_1 C × B	1606	59.4	5.5	60.9	27.5	54.9	30.2
Nec. diff.							
5% point	134	2.2	0.6	4.3	1.2	1.4	
1% point	182	2.9	0.8	5.8	1.7	1.8	

* Unduly low for Sunrise because of killing frost before maturity.

height, larger head size, and larger seed of the single crosses. They also display a very desirable oil content and satisfactory kernel percentage.

As pointed out previously several single crosses were made in 1942 by natural crossing technique. These were included in tests in 1943 at several experimental stations on the prairies. The data from the test at Saskatoon are given in Table 4.

TABLE 4.—COMPARISON OF 5 SINGLE CROSSES WITH MENNONITE, SUNRISE AND 1 INBRED PARENT TESTED AT SASKATOON, 1943

Material	Yield per acre	Plant height	Head diameter	1000 seed wt.	Weight per bushel	Percentage kernel	Percentage hybrids
	lb.	in.	in.	gm.	lb.	%	%
Sunrise	223	40.7	4.1	28.4	29.6	56.0	
Mennonite	976	51.3	4.1	52.4	29.3	58.0	
Inbred B	566	40.3	5.1	35.3	31.4	59.0	
F_1 C × B	1285	48.0	4.6	44.8	34.2	61.0	89.[illegible]
F_1 C × Sunrise	1405	45.3	6.0	47.4	32.9	62.0	95.2
F_1 Sunrise × C	691	44.0	4.7	42.0	31.0	59.0	33.2
F_1 Sunrise × B	811	43.3	5.5	45.0	31.0	58.0	43.6
F_1 D × C	609	40.7	4.2	38.1	31.3	62.0	
Nec. diff. 5% point	518	N. sig.	N. sig.	7.19	*	3.9	

* Insufficient seed to analyse on single plot basis and therefore no variance analysis is possible.

While Table 4 shows that the single crosses differed greatly in yielding ability it is evident that those which showed a high percentage crossing (C × B and C × Sunrise) were substantially higher in yield than all other material in the test. The data again indicates a relationship between yield and percentage crossing. The yield per acre of C × Sunrise with 95.2% crossing was 1405 pounds while that of Sunrise × C with 33.2% crossing was only 691 pounds per acre. Similarly the cross Sunrise × B

with 43.6% crossing was not outstanding. However, the relationship between percentage crossing and yield was exaggerated by the low yield of Sunrise. This variety yielded poorly because of frost damage before maturity, therefore the Sunrise selfs and sibs occurring in the single crosses contributed in only a small degree to the yield. This is shown by the fact that seed harvested from the cross Sunrise × B showed that 96.8% was from hybrid plants. In addition to the frost damage, competition from the more vigorous and earlier maturing hybrid plants depressed the yield of Sunrise selfs and sibs.

The low percentage crossing obtained in some of the single crosses involving Sunrise is partially accounted for by the lack of simultaneous flowering of the members of paired lines in the natural crossing plots. In addition, it has been observed that Sunrise is a heavy pollen producer and more self-fertile and consequently makes a poorer female parent than other lines.

No concrete explanation can be offered for the comparatively poor performance of the single cross D × C. It was impossible to determine the percentage crossing in this material but since Line C, as pointed out above, is a poor pollen producer the crossing percentage may have been low. It is also possible that Line D has poor combining ability. With the information available it is impossible to determine whether either or both of these factors provide an adequate explanation of the poor yielding behaviour of this cross.

In previous years plants of the single cross C × B had been taller growing and had larger heads than Mennonite or the inbred lines. In 1943 there was very little relationship between height, head diameter and yield. It should be pointed out that for ease of harvesting, relatively short growth is desirable and in this respect the single crosses are just as satisfactory as Mennonite. Contrasted to Mennonite the high degree of uniformity of the single crosses for height, head size, stem strength, and seed size is definitely desirable.

In 1943, tests involving single crosses, Sunrise, Mennonite originating from different locations, and three 1942 Scott selections were conducted at a number of experimental stations in the Prairie Provinces. A summary of the yield data is presented in Table 5.

Variance analysis showed highly significant differences between the material in the tests. Varieties × stations interaction was also highly significant, indicating that the different varieties and single crosses reacted differently at the different stations. The performance of the single crosses in some of these tests is somewhat disappointing. However, it should be kept in mind that in only the cross C × B was there a relatively high percentage crossing (89.0%). As an average of all tests this single cross gave the highest yield and significantly outyielded all but 2 strains. Although at 3 stations the yield of C × B was lower than some other strains the differences were not significant. As pointed out in the case of the Saskatoon test the yields of single crosses Sunrise × C, and Sunrise × B were unduly depressed by the presence of high proportions of Sunrise selfs and sibs. The low yield of the cross Sunrise × E is probably largely due to the fact that very few hybrid plants were observed in this single cross, and practically

TABLE 5.—SEED YIELDS FROM THE STATION TESTS OF VARIETIES AND SINGLE CROSSES.

Material	Yield (lb. per acre)							Grand average
	Saskatoon	Scott	Swift Current	Melfort	Indian Head	Lethbridge	Morden	
F_1 Sunrise × E*	392	28	336	227	694	387	1986	579
F_1 D × C	609	378	1290	1451	908	941	2107	1098
F_1 Sunrise × C	691	189	950	1121	719	911	2249	976
F_1 C × B	1285	521	1304	1834	920	1204	2493	1368
F_1 Sunrise × B	811	260	1408	935	850	695	2402	1052
Menn. (Rost. orig.)	1182	433	1295	1878	886	1047	2072	1256
Menn. (Man. orig.)	952	409	1191	1723	883	671	2209	1148
Menn. (Winkler, Man.)	691	161	967	1337	418	1358	2219	1024
Sunrise	174	74	251	204	856	418	2054	576
Scott Seln. No. 1	926	493	1182	1917	1121	914	1997	1221
Scott Seln. No. 2	1463	363	1059	1735	958	817	1917	1185
Scott Seln. No. 3	1175	410	1119	1737	417	794	2353	1143
Nec. diff. 19 : 1 odds	325	194	319	351	N. sig.	336	N. sig.	169
Nec. diff. 99 : 1 odds	444	263	436	480		460		219

* = S-488 a line very similar to Sunrise introduced from Russia.

all the harvested seed was from Sunrise plants. Reliable information on the yielding ability of these various combinations of inbred lines in single crosses can be obtained only when combinations having a high percentage crossing are secured.

CONCLUSIONS

Although the data presented show that inbreeding brings about a lowering of yield and vigour in sunflowers, inbreeding is of value in eliminating undesirable genes and in bringing about uniformity for desirable characters such as non-branching strong stems, earliness, small seed size, and high oil content. Because of their low yield inbred lines will probably not be of value as commercial varieties. Morozov and Ananeva (5) of the Saratov Experimental Station report that during 19 years of inbreeding sunflowers no strains materially superior to the original forms had been obtained by selective inbreeding alone. As in the case of corn, the value of inbreeding sunflowers appears to be for production of lines breeding true for desirable characters which can then be used in combinations to produce single cross hybrids.

The high yield of single crosses is contingent upon securing a high degree of crossing between the paired inbred lines. To accomplish this the selection of lines with similar flowering periods or the controlling of time of flowering by staggering seeding dates is essential. Unless the paired lines differ in pollen yield and, or, self-fertility it appears that both inbred lines will cross to about the same extent and therefore seed from both could be used commercially. If one line of a pair is a heavy pollen producer and fairly self-fertile it may not cross sufficiently to warrant using its seed with the reciprocal for the production of the commercial crop.

As far as possible it would be desirable to have one or both lines carry marker genes so that the extent of crossing could be determined. Unless this determination is possible in the seedling stage it would be advisable

to withhold distribution of the hybrid seed for commercial production for a year to permit the determination of the degree of crossing. If the marker characters are displayed in the seedling the determination of extent of crossing could be done in greenhouses in the winter months.

It may be possible to offset the effect of fairly low percentage crossing by increasing the seeding rate. This has been indicated in the data presented but a good deal of further work needs to be done on this problem.

A word should be said about the feasibility of the use of double crosses. This would be very desirable since larger yields of crossed seed would be obtained. While as yet no attempt has been made to produce double crosses, it has been noticed that F_1 hybrids are very self and possibly sib-fertile. This would likely limit the extent of natural crossing between two isolated single crosses and result in a fairly low proportion of double crossed seed. However, it is impossible to reach any definite conclusions on this question until it has been investigated.

SUMMARY

1. The open fertilized progeny of 2 selections were compared to the 1st to 4th generation inbred progenies of these selections using a randomized split plot design with 3 replicates. Four generations of inbreeding reduced the average yield of the 2 selections by 60.3%. The greatest drop in yield occurred in the first generation being 35.6%. Inbreeding in a similar way reduced plant height and head size.

2. Selective inbreeding resulted in a high degree of uniformity for such desirable characters as date of maturity, stem type and strength, seed size, percentage oil, and other characters.

3. Reciprocal single crosses made by hand pollination between 2 inbred lines outyielded the average of the inbred parents by 247%. The increase over Mennonite grown in an adjacent test was 60.8%. The same single cross obtained by natural crossing outyielded Mennonite by 47.4%.

4. Crossing as high as 95.2% has been obtained in isolated natural crossing plots. Differences in date of flowering of the 2 lines being crossed was apparently one of the main causes for a low extent of natural crossing. By later seeding of the earlier flowering line it is possible to obtain simultaneous flowering.

5. Differences in pollen productivity and the degree of self fertility of the 2 lines also appear to influence the extent of natural crossing.

6. An indication of a positive relationship between extent of natural crossing and yield was found. In commercial production it would be desirable to determine the degree of crossing obtained before releasing the seed to growers.

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TREATING, PACKAGING AND STORING POTATO EYE SETS[1]

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Eye sets are becoming an increasingly important factor in the seed potato trade of the Prairie Provinces, mainly because they can be widely distributed at little cost. Seed houses can ship eye sets by express, parcel post, or airmail, and sets from certified seed potatoes are made available in this way to many potato growers who do not have ready access to the regular certified seed potato trade.

The biggest demand for eye sets has been from farmers who grow potatoes only for their own use. A farmer can buy a 50-eye set package for a nominal outlay and produce from 50 to 100 pounds of good seed potatoes for planting the following year.

The eye set has a large cut surface which exposes it to deterioration from fungi, bacteria, and excessive loss of moisture. The methods that have been used by seed houses in preparing, treating and packaging eye sets to prevent deterioration have not always been successful, and the sets have not always given satisfactory results. Scannell (2) at Indian Head found that yields from eye sets of the same variety but from different sources varied widely, and subsequent tests at Edmonton gave similar results. To assist seed houses in developing an assured method of handling eye sets, experiments were started at Edmonton in 1937 by the District Inspector Seed Potato Certification, Dominion Department of Agriculture and as the work progressed from year to year the following phases of the problem were studied:—

1. Treating potatoes before eye sets are cut.
2. Size of eye set.
3. The best treatment of eye sets after they are cut and before packaging.
4. The most suitable package for eye sets.
5. The effect of storage temperature on the keeping quality of eye sets.

MATERIALS AND METHODS

Early Ohio and Carter's Early Favorite potatoes from fields that passed inspections for seed certification were used throughout the experiments.

A vegetable baller was used to cut ½-ounce eye sets approximately ⅞ inch in depth.

A wax-coated carton, wrapped with waxed kraft paper was used as the standard package. This held 25 eyes, which represented one replicate

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in the test. The eyes were planted 18 inches apart, in rows 3 feet apart. A simple randomized plan was used for each experiment. Ten replicates were made for all tests except in 1941 and 1942, when only 5 replicates were planted.

RESULTS

Treating the Tubers before Eyes Are Cut

Tests were made on the treatment of tubers with an organic mercury dip in 1940, 1941 and 1942. The eye sets were then cut and stored from 3 to 4 weeks at 60° F. to 65° F. before being planted.

The tubers used in the 1940–41 tests were taken from a crop in which storage rot was present before grading. No storage rot was present in the crop from which the 1942 tubers were selected.

TABLE 1.—TUBER TREATMENT

Treatments	1940		1941		1942	
	Stand	Average yield of 10 replicates	Stand	Average yield of 5 replicates	Stand	Average yield of 5 replicates
	%	lb.	%	lb.	%	lb.
Tubers treated and eye sets washed	—	—	96.0	39.2	98.4	69.6
Tubers treated and eye sets dusted	44.0	30.8	—	—	98.4	70.6
Tubers not treated and eye sets washed (check)	—	—	48.8	24.6	97.2	67.8
Tubers not treated and eye sets dusted (check)	0.0	0.0	16.8	6.2	96.8	66.0

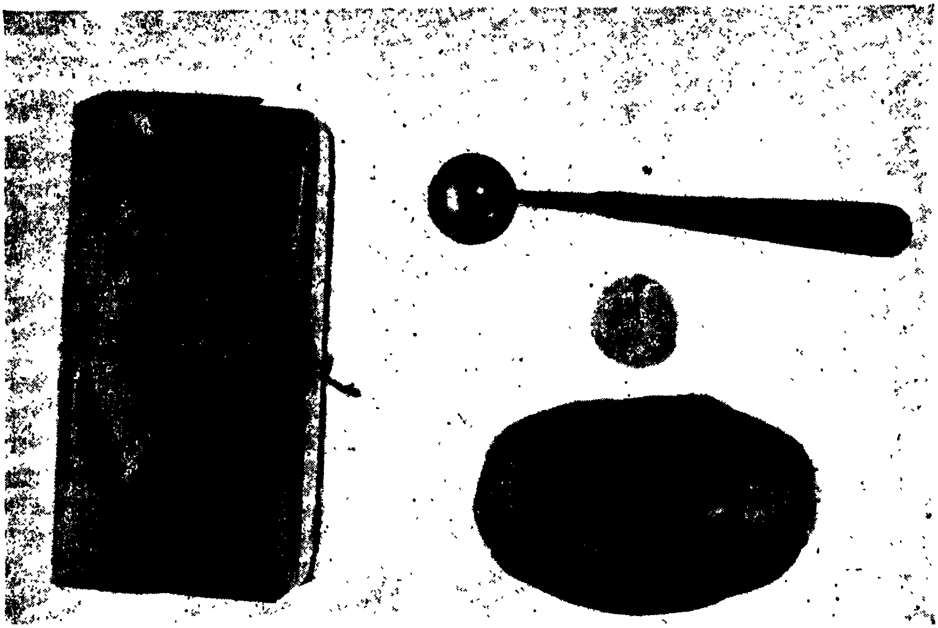
Potato eyes cut from tubers that were treated with an organic mercury dip in 1940–41 gave significantly better stands and yields than eyes cut from untreated tubers. Optimum growing conditions, and the absence of storage rot in the potato stock in 1942 gave satisfactory stands and yields from eye sets from both treated and untreated tubers; but even under those optimum conditions, potato eyes cut from treated tubers gave the better results.

Size of Eye Sets

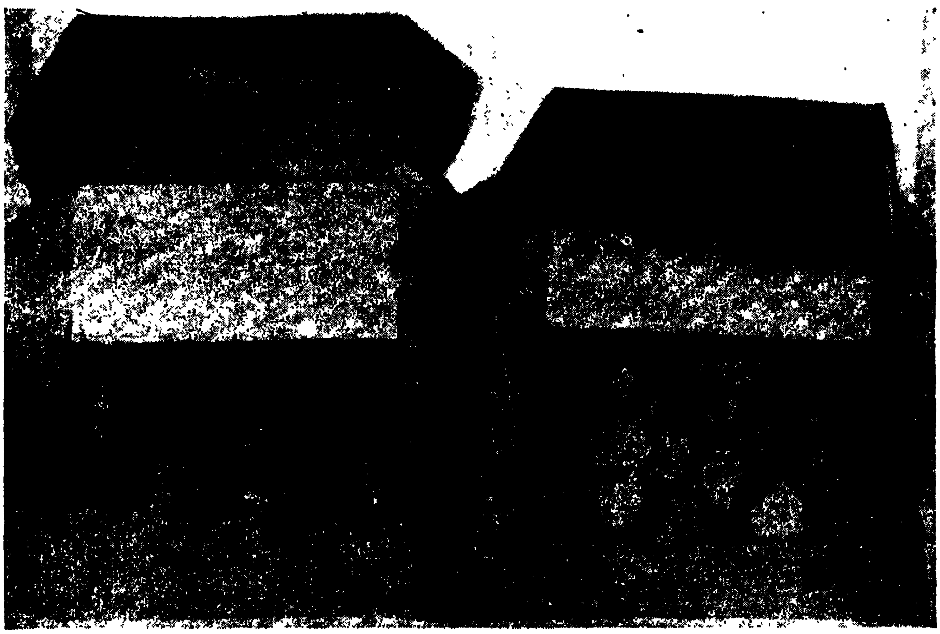
As eye sets are shipped by parcel post, and sometimes by air mail they must not be too large for economic distribution, but they should be cut large enough to ensure a satisfactory crop. If the eye set is too small, there is not only a greater danger of deterioration from loss of moisture, but yields are definitely decreased. Bushnell (1) summarizes a review of literature on potato yields as affected by size of sets, as follows:

"There is in general a gradual decrease in yield from the largest seed piece tested to seed pieces ½ ounce in size. There is a much greater decrease in yield as you decrease the weight of a set below this point."

This indicates that if the best results are to be obtained, it is important to cut eye sets about a ½ ounce in weight. Table 2 gives the results of the test made in 1937 with different weights of eye sets.



A wax coated carton wrapped with wax kraft paper as shown above, is a satisfactory package for storing and shipping eye sets. The tool used to cut the eye sets is shown on the right.



The eye sets on the right are dusted with ground limestone while those on the left are washed under running water.

TABLE 2.—DIFFERENT WEIGHTS OF EYE SETS

Weight in grams and percentage of 1 ounce	Stand	Average yield of 10 replicates
	%	lb.
15 grams—53%	92.8	50.5
12 grams—42%	91.6	50.8
9 grams—32%	81.6	42.9
6 grams—21%	88.4	41.5
3 grams—11%	81.[illegible]	37.0
2 × S.E. of Diff.	1.8	4.1

The test indicates that the depth, as well as the weight of the eye set is important. The 9-gram and the 3-gram sets were shallow and gave the lowest yields in relation to weight. Further tests in 1938 indicated that it was necessary to cut the eye sets at least $\frac{7}{8}$ inches in depth to obtain good results.

Treatment of Eye Sets

Slaked lime, ground limestone, and magnesium limestone have been used by seed houses to dust potato eyes after they were cut and before packaging, and these materials were tested, as well as other dusts. Slaked lime proved unsatisfactory, as it sometimes injured the sets, while flours of sulphur decreased the vigour of the sets which resulted in lower yields. Ground limestone and magnesium limestone were among the most satisfactory materials tested.

TABLE 3.—TREATING EYE SETS

Treatment	Stand	Average yield of 5 replicates
	%	lb.
Washed in water	76.8	31.2
Traumatic acid 1-1000	76.8	33.8
Traumatic acid 1-2000	72.0	27.2
Washed in water and dusted	55.2	23.4
Traumatic acid 1-1000 dusted	52.0	21.3
Traumatic acid 1-2000 dusted	48.8	19.6
No treatment	49.6	19.5
Dusted	40.8	20.8

In 1940 traumatic acid, a hormone that stimulates cork formation was tested, but without definite result. The test, however, indicated the increased value of washing potatoes in water over other treatments.

Experiments were designed in 1941 and 1942 to determine more fully the value of washing potato eyes in water before packaging. A check treatment of chloride of lime and distilled water was included, as Edmonton tap water, which was used, contains a small amount of chloride of lime.

TABLE 4.—WASHING EYE SETS

Treatment	1941		1942	
	Stand	Average yield of 20 repl.	Stand	Average yield of 5 repl.
	%	lb.	%	lb.
Chloride of lime	88	33.6	98.4	68.4
Washed in water	88.0	32.2	97.2	67.8
Washed under running water	87.0	31.4	—	—
Washed in distilled water	84.2	32.8	95.2	62.2
Untreated	61.0	17.9	92.0	62.0
Dusted with magnesium limestone	—	—	96.8	66.0

There was very little difference in the lots that were washed in the 1941 tests. All check plots planted with eye sets that were untreated, however, gave significantly lower yields.

In the 1942 test, all treatments, including the dusted and untreated checks, produced good stands and yields. This was probably due to the optimum growing conditions that prevailed, and the absence of storage rot in the stock from which the eye sets were cut, and indicates that under favourable conditions dusting and packaging the eye sets as cut will give as good results as washing. The tests in 1940 and 1941, however, indicate that washing the potato eyes gives better results under less favourable conditions. It is, therefore, a more reliable treatment.

Most Suitable Package for Potato Eyes

Moisture-tight packages have proved to be the most suitable containers for eye sets. Sets packed in such containers do not lose weight from loss of moisture, and the vitality of the set is maintained. The danger of rapid deterioration due to fungi and bacteria is also less.

In 1939 and 1942 the differences in stand and yield were not significant, because conditions were favourable. In 1939 the packages of eye sets were held under ideal storage temperatures. In 1942 lack of storage rot

TABLE 5.—PACKAGE TEST

Type of package	1938		1939		1940		1941		1942	
	Stand	Average yield	Stand	Average yield	Stand	Average yield	Stand	Average yield	Stand	Average yield
	%	lb.	%	lb.	%	lb.	%	lb.	%	lb.
Wax coated carton with wax kraft paper wpd.	96.8	77.0	84.0	16.0	98.0	46.9	82.0	39.0	99.2	68.4
Wax coated carton only	—	—	79.6	15.6	—	—	42.4	28.0	—	—
Carton not wax coated or wax kraft wrapped	52.8	37.0	75.6	14.1	20.4	16.7	25.6	15.0	94.4	64.0
2 × S.E. of Diff.		11.2				6.2		3.7		

in the stock that was used also had a favourable influence on the keeping quality in all types of containers. In 1940 and 1941 storage rot was present in the stock used, and significant differences were obtained.

Storage Temperature for Potato Eyes

In the 1938 experiments it was found that packages of potato eyes stored under different temperatures showed definite differences in keeping quality, especially when the storage period extended to two or three weeks. In 1939 a test was made with storage temperatures of 77° F., 68° F., 59° F. and 50° F. This test has been continued each year since, with a 38° F. test included in 1941 and 1942.

TABLE 6.—STORAGE TEMPERATURES

Storage temper-ature	1939		1940		1941		1942	
	Stand	Average yield	Stand	Average yield	Stand	Average yield	Stand	Average yield
	%	lb.	%	lb.	%	lb.	%	lb.
77° F.	95.6	17.6	88.0	45.5	94.4	30.7	96.0	59.0
68° F.	75.6	13.4	3.2	2.0	80.8	31.1	97.6	62.4
59° F.	61.2	10.6	6.8	4.0	48.6	21.1	98.4	57.4
50° F.	70.4	12.6	5.2	4.0	71.2	22.2	99.2	63.4
38° F.	—	—	—	—	85.6	25.4	98.4	63.4
2 × S.E. of Diff.		3.78				3.86		

This test indicated that 77° F. was the most reliable, and 59° F., the most unreliable storage temperature. The favourable results obtained with the 77° F. storage were probably due to the more rapid cork formation.

CONCLUSION

The following procedure is recommended as a result of the experiments that have been conducted:

(1) Carefully select the certified seed stock from which the eyes are to be taken. Only stock that has been free during storage period from frost and storage rot should be used. The best time to find this out is before the potatoes have been graded.

(2) Treat tubers before eye sets are cut. Good results have been obtained from an organic mercury dip.

(3) Use a cutting tool that will cut an eye set at least $\frac{7}{8}$ inch in depth and $\frac{1}{2}$ ounce in weight.

(4) Wash the potato eyes in clean water as soon as they are cut. Dusting the eye sets with limestone or magnesium limestone has given good results some years, but has not been as reliable as washing the sets with water.

(5) Package eye sets, as soon as they are washed, in a moisture proof type container. A wax coated carton, wrapped with waxed kraft paper is a reliable package for keeping eye sets in good condition.

(6) Store the eye sets at about 77° F. from four days to a week, and then at 38° F. until shipped. The next best storage is 38° F. continuously. Storages around 60° F. should be avoided.

ACKNOWLEDGMENTS

Acknowledgment is made for the assistance given in field plot technique and statistical analysis by Dr. W. C. Broadfoot and Dr. A. McCalla; and also the co-operation, without which the experiments would not have been possible, of the Field Crops Department of the University of Alberta, who loaned an acre of land each year and assisted in the cultivation and harvesting of the crop.

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CROWN ROT OF APPLE TREES IN BRITISH COLUMBIA—ROOTSTOCK AND SCION RESISTANCE TRIALS[1]

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The trials reported herein are the first of a series that is being made at the request of the Experimental Farms Service as an adjunct to the work of evaluating the suitability of various apple stocks for British Columbia conditions. Since the root crown rot that is caused by *Phytophthora cactorum* is a most prevalent disease in the largest fruit growing region of this province, the Okanagan Valley, resistance to it is a very desirable character. That various stocks might be expected to display differences in susceptibility and resistance was indicated by results obtained in earlier work by Welsh (2) and by the work of Baines (1) on the apple tree trunk canker, the collar rot of Indiana, which is also caused by a strain of *P. cactorum.*

In addition to the resistance trials proper, an experiment to determine whether depth of planting had an effect on the incidence of crown rot was made. As the varieties used in this latter experiment were for the most part the same as those on trial for resistance, the results of this experiment are also included in this report.

The material used was selected, propagated, planted, and cared for by the Experimental Farms Service. For this, and for the design of the field plans, particular credit is due Messrs. A. J. Mann and R. C. Palmer of the Summerland Experimental Station, B.C. In all 1,560 trees, in which were represented 40 different varieties and rootstocks, were planted.

MATERIAL AND METHODS

PLANTING PLAN

Resistance Trials Experiment

The trees were planted 3 feet apart in rows 6 feet apart. There were 24 rows of 52 trees each. Each root-scion combination was originally represented by 16 trees, but in some cases not all survived to the time of testing; casualties were particularly high in the "own-rooted" trees. To compensate for soil variation, the 24 rows were divided into 4 contiguous blocks of 6 rows each. The 16 trees of each combination were split up into groups of 4 and each group placed in a different position in the corresponding rows of the 4 blocks. The arrangement was such that the position of the groups relative to the ends of the rows was different in each block, although the order of the combinations in the rows was the same.

The trees were planted in the spring of 1941, and were then 1 year old.

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Depth of Planting Experiment

The depth of planting experiment was conducted in a block similar in size and contiguous to those of the resistance trials. In this block, however, the rows were identical, both in composition and order of planting. Each root-scion combination was represented by 12 trees, 2 in each of the 6 rows. Three depths of planting were used; the first and fourth row with the root-scion union 4 inches below the ground line, the third and sixth with the unions at the ground line, and the second and fifth with the unions 4 inches above it.

INOCULATION

A mixture of four isolates[5] of *P. cactorum*, derived from widely separated crown rotted trees, was used as inoculum. The isolates were cultured separately on a mixture of corn meal, sand, and pea extract, and the cultures mixed together just before use.

The inoculations were made by cutting out vertical strips of bark approximately 3/16 inches wide and smearing the inoculum on the cambium thus exposed. No attempt was made to standardize the vertical length of the cut, as this naturally varied with the character of the individual tree, but care was taken to confine the cut to either root or scion, or both, as the test required. Only in those trees in the depth of planting experiment was the inoculation made directly across the union. In the case of the scion tests, the soil was mounded around the base of the trees so that about 3 inches of scion was covered and the wound so protected from immediate drying out.

The inoculations were made during May and June in 1942 on the north sides of the trees. Those trees that had developed no rot by the spring of 1943 were reinoculated during June and July in 1943, this time on the south side.

RESULTS

Resistance Trials Experiment

These trials terminated in the fall of 1943. Records of the extent and position of rot were taken in October. These are presented in Table 1 for the rootstocks and in Table 2 for the scions. In the tables will be found the varietal composition and number of trees of each combination, the percentage that developed crown rot, and an arbitrary disease rating.

The method of arriving at the arbitrary disease rating was as follows: When the records were taken the amount of rot present on each tree was evaluated and noted: no rot, 0; a trace of rot (but less than one-quarter girdling), 0.5; about one-quarter girdling, 1; about one-half girdling, 2; about three-quarters girdling, 3; complete girdling, 4. The disease rating for each combination of root and scion was derived by expressing the sum of the figures so obtained as a percentage of the total possible for that combination had all of the trees been completely girdled. For example, in the combination Malling II root and Red Jonathan scion there were 16 trees (Table 1). Of these, 2 showed a trace of rot in the root or a total of 1. The total possible for 16 trees is 64. Therefore, the disease rating for the

[5] These were:—No. 229 (Summerland, B.C.).
No. 452 (Osoyoos, B.C.).
No. 558 (Summerland, B.C.).
No. 594 (Vernon, B.C.)

TABLE 1.—PATHOGENICITY OF *Phytophthora cactorum* ON VARIOUS APPLE ROOTS ARTIFICIALLY INOCULATED FOR TWO SUCCESSIVE YEARS WITH A MIXED CULTURE OF FOUR ISOLATES

Roots inoculated	Varietal composition of tree: Root	Varietal composition of tree: Scion	Roots developing crown rot	Disease rating
number			%	
	Seedling roots			
16	Anis	Antonovka	0	0
16		Hibernal	25	20
16		Pyrus baccata	6	6
48			10	9
16	Antonovka	Charlamoff	0	0
16		Hibernal	0	0
16		Virginia crab	0	0
48			0	0
16	Canada Baldwin	Antonovka	44	37
16		Charlamoff	50	37
14		Hibernal	36	34
16		Jubilee	25	22
16		Spartan	19	17
10		Stirling	40	31
16		Virginia crab	69	66
104			40	35
16	Columbia	Columbia	6	6
16		Virginia crab	12	11
32			9	8
16	Duchess	Antonovka	19	8
16		Charlamoff	44	30
16		Hibernal	31	25
16		Virginia crab	69	61
64			41	31
16	Martha	Beauty	19	16
16		Haas	6	6
16		Tony	19	14
16		Virginia crab	19	19
64			16	14
15	McIntosh	Stirling	40	30
15	Pyrus robusta	Pyrus baccata	7	5
16	Wealthy	Hibernal	6	5
15	Yellow Transparent	Hibernal	33	22
16		Charlamoff	63	49
16		Virginia crab	81	67
47			60	46

TABLE 1.—PATHOGENICITY OF *Phytophthora cactorum* ON VARIOUS APPLE ROOTS ARTIFICIALLY INOCULATED FOR TWO SUCCESSIVE YEARS WITH A MIXED CULTURE OF FOUR ISOLATES—*concluded*

Roots inoculated	Varietal composition of tree		Roots developing crown rot	Disease rating
	Root	Scion		
number	*Malling roots*		%	
16	Malling I	McIntosh	37	22
16		Newtown	37	26
16		Red Winesap	50	27
16		Turner Red	88	61
64			53	34
16	Malling II	McIntosh	0	0
16		Newtown	0	0
16		Red Jonathan	12	2
16		Red Winesap	19	8
16		Turner Red	6	6
80			7	3
16	Malling IX	McIntosh	6	6
16	Malling XVI	McIntosh	25	18
	Own roots			
15	Anis		20	20
15	Antonovka		0	0
13	Canada Baldwin		77	63
14	Charlamoff		21	11
2	Delicious		0	0
15	Hibernal		13	13
14	Jubilee		0	0
14	McIntosh		0	0
10	Melba		0	0
16	Virginia crab		0	0
11	Wealthy		9	2
10	160 (stock number)		10	10

Malling II root is $(1 \div 64) \times 100 = 1.56$, or 2 expressed to the nearest whole number. In the Columbia root and Virginia crab scion combination there were likewise 16 trees. Of these, 2 also showed rot, but here one was three-quarters and the other completely girdled giving a total of 7. Therefore, the disease rating for the Columbia root is $(7 \div 64) \times 100 = 11$. It will be noted that in both cases the percentage of roots developing crown rot is the same, namely, 12%.

As the number of trees used in each individual combination was relatively small, neither the figure for percentage of trees developing rot nor that for disease rating can be considered anything more than indicative when the combinations are considered separately. However, some of the varieties were represented in more than one combination and when these are treated as a group the figures become more significant. Thus, in Table 1, Anis, Antonovka, Canada Baldwin, Columbia, Duchess, Martha, Malling I, and Malling II, can be so treated and for each a total percentage and disease rating figure has been calculated.

TABLE 2.—PATHOGENICITY OF *Phytophthora cactorum* ON VARIOUS APPLE SCIONS ARTIFICIALLY INOCULATED FOR TWO SUCCESSIVE YEARS WITH A MIXED CULTURE OF FOUR ISOLATES

Scions inoculated	Varietal composition of tree		Scions developing rot	Disease rating
	Seedling root	Scion		
number			%	
16	McIntosh	Antonovka	0	0
16	McIntosh	Bedford	37	12
16	McIntosh	Canada Baldwin	44	33
16	McIntosh	Charlamoff	6	3
16	McIntosh	Delicious	0	0
16	McIntosh	Dolgo	0	0
16	McIntosh	Florence	6	2
16	McIntosh	Grimes Golden	37	32
16	McIntosh	Haas	0	0
16	McIntosh	Haralson	0	0
16	McIntosh	Hibernal	19	17
16	McIntosh	Hyslop	44	41
14	McIntosh	Jubilee	7	7
12	McIntosh	McIntosh	0	0
16	Canada Baldwin	Newtown	0	0
16	McIntosh	Olga	69	61
16	McIntosh	Osman	12	12
28	McIntosh	Pyrus baccata	39	27
16	McIntosh	Robin	0	0
15	McIntosh	Spartan	0	0
16	McIntosh	Tony	6	3
16	McIntosh	Transcendent	0	0
16	McIntosh	Virginia crab	6	5
16	McIntosh	Winesap	12	8
16	McIntosh	Winter St. Lawrence	81	81
4	McIntosh	Wolf River	75	75

Depth of Planting Experiment

The records for the depth of planting experiment were taken at the same time as were those for the resistance trials and are summarized in Table 3. In the trees planted with the union at the ground line, slightly more rot developed in the roots than in those planted deeper or shallower, and deep planting was more conducive to rot in the scion than was ground line or shallow planting. However, there was little significant difference in the total amounts of rot which developed on the three groups.

TABLE 3.—EFFECT OF DEPTH OF PLANTING ON INCIDENCE OF CROWN ROT*

Depth of planting	Rot in roots		Rot in scions		Total rot in trees	
	Affected trees	Disease rating	Affected trees	Disease rating	Affected trees	Disease rating
	%		%		%	
Union 4" below ground line	20	16	25	20	34	28
Union at ground line	31	22	17	13	38	28
Union 4" above ground line	22	15	18	12	33	21

* There were 104 for each depth; 52 combinations represented; inoculated for 2 successive years with a mixed culture of 4 isolates, *Phytophthora cactorum*; inoculation across union.

TABLE 4.—PATHOGENICITY OF *Phytophthora cactorum* ON VARIOUS APPLE ROOTS AND SCIONS BASED ON THE RESULTS OF THE DEPTH OF PLANTING EXPERIMENT*

Crown rot in root		Varietal composition of tree		Crown rot in scion	
Roots developing crown rot	Disease rating	Seedling root	Scion	Scions developing crown rot	Disease rating
%				%	
8	8	Antonovka	Charlamoff	17	9
8	1		Virginia crab	0	0
8	5				
42	27	Canada Baldwin	Antonovka	0	0
33	29		Charlamoff	33	26
38	28				
0	0	Columbia	Columbia	8	1
25	17	Duchess	Antonovka	0	0
75	45		Charlamoff	25	15
75	61		Virginia crab	33	22
58	41				
33	25	Martha	Beauty	58	50
0	0		Haas	0	0
17	8		Tony	8	6
25	11				
42	25	McIntosh	Bedford	17	10
8	8		Canada Baldwin	17	17
17	15		Dolgo	0	0
25	14		Haas	0	0
17	10		Hyslop	50	36
17	12		Olga	42	38
8	8		Osman	0	0
8	4		Pyrus baccata	25	17
0	0		Robin	0	0
33	25		Tony	25	19
17	12		Transcendent	8	4
42	27		Winter St. Lawrence	92	81
20	13				
8	8	Pyrus robusta	Pyrus baccata	33	25
42	28	Yellow Transparent	Antonovka	0	0
42	35		Charlamoff	33	25
42	32				

* Inoculation across the union for 2 successive years with a mixed culture of 4 isolates; each combination represented by 12 trees.

Since the combinations used in the depth of planting were, for the most part, ones which were also used in the resistance trials experiment, and since depth of planting had so little influence on the incidence of crown rot, the results in the individual combinations used here may be compared with those obtained from the resistance trials. Table 4 gives the stock-scion combinations used and the percentage and disease ratings for each.

DISCUSSION OF RESULTS

It must be emphasized again that the results obtained from these trials can be considered to be indicative only. This is particularly true for the results on individual combinations and where the material was represented only once in the various combinations, as this meant a test on 16 trees or less. On the other hand, much of the material was represented in several combinations in the resistance trials experiment or occurred both in this and in the depth of planting experiment; moreover, the maternal parents of some of the seedling roots were used on their own roots or as scions on other rootstocks. By combining all of this information a very fair estimate of the comparative resistance and susceptibility of much of the material can be made. Table 5 which lists the disease ratings as obtained from these various sources may be used for this purpose.

It will be seen from Table 5 and the preceding tables that certain varieties and their seedlings showed a consistently higher degree of susceptibility than did others. Eleven: Beauty, Canada Baldwin, Duchess, Hyslop, Grimes Golden, Malling I, Olga, Winter St. Lawrence, Yellow Transparent, Wolf River, and *Pyrus baccata*, have all proved to be highly susceptible. Eleven: Anis, Bedford, Charlamoff, Hibernal, Malling XVI, Martha, McIntosh, Osman, Stock 160, Tony and Virginia crab, were at least partially susceptible. Seven: Antonovka, Columbia, Dolgo, Haas, Malling II, Robin and Transcendent were quite resistant. Eleven: Delicious, Florence, Haralson, Jubilee, Malling IX, Melba, Newtown, *Pyrus robusta*, Spartan, Wealthy, and Winesap, although showing good resistance, must still be considered to be in doubt because of inadequate numbers and lack of cross checks.

While the evaluation of resistance and susceptibility which was obtained from these trials is probably substantially correct, the possibility that one partner of the root-scion combination may have a modifying effect on the resistance of the other, should not be overlooked. Some evidence that such an effect exists may be seen in the behaviour of Virginia crab on the various rootstocks with which it was combined. This variety was found to be relatively resistant. The 16 own-rooted trees showed no crown rot, and when used as a scion on the resistant Antonovka root, only a trace of rot developed in 1 tree out of 28 inoculated. On the other hand, when Virginia crab was used on the susceptible seedling roots of Canada Baldwin, Duchess, and Yellow Transparent, the incidence of crown rot in these seedling roots was far greater than when these seedlings were combined with any other variety, in some cases the disease rating being double the average rating for these roots.

SUMMARY

The susceptibility of 40 different apple varieties and seedlings to the crown rot caused by *P. cactorum* in British Columbia was compared by artificially inoculating 1,560 trees.

TABLE 5.—CROWN ROT DISEASE RATINGS (TOGETHER WITH NUMBERS OF TREES ON WHICH THESE RATINGS ARE BASED) OF VARIOUS APPLE VARIETIES AND SEEDLINGS AS OBTAINED IN THE DIFFERENT EXPERIMENTS

Material	Seedling		Variety		
	Resistance trials	Depth of planting	Own-rooted	Scion on other roots: Trials	Scion on other roots: Depth of planting
Anis	9 (48)	— —	20 (15)	— —	— —
Antonovka	0 (48)	5 (24)	0 (15)	0 (16)	0 (36)
Beauty	— —	— —	— —	— —	50 (12)
Bedford	— —	— —	— —	12 (16)	10 (12)
Canada Baldwin	35 (104)	28 (24)	63 (13)	33 (16)	17 (12)
Charlamoff	— —	— —	11 (14)	3 (16)	19 (48)
Columbia	8 (32)	0 (12)	— —	— —	1 (12)
Delicious	— —	— —	0 (2)	0 (16)	— —
Dolgo	— —	— —	— —	0 (16)	0 (12)
Duchess	31 (64)	41 (36)	— —	— —	— —
Florence	— —	— —	— —	2 (16)	— —
Grimes Golden	— —	— —	— —	32 (16)	— —
Haas	— —	— —	— —	0 (16)	0 (24)
Haralson	— —	— —	— —	0 (16)	— —
Hibernal	— —	— —	13 (15)	17 (16)	— —
Hyslop	— —	— —	— —	41 (16)	36 (12)
Jubilee	— —	— —	0 (14)	7 (14)	— —
Malling I	— —	— —	34* (64)	— —	— —
Malling II	— —	— —	3* (80)	— —	— —
Malling IX	— —	— —	6* (16)	— —	— —
Malling XVI	— —	— —	18* (16)	— —	— —
Martha	14 (64)	11 (36)	— —	— —	— —
McIntosh	30 (15)	13 (144)	0 (14)	0 (12)	— —
Melba	— —	— —	0 (10)	— —	— —
Newtown	— —	— —	— —	0 (16)	— —
Olga	— —	— —	— —	61 (16)	38 (12)
Osman	— —	— —	— —	12 (16)	— —
Pyrus baccata	— —	— —	— —	27 (28)	21 (24)
Pyrus robusta	5 (15)	8 (12)	— —	— —	— —
Robin	— —	— —	— —	0 (16)	0 (12)
Spartan	— —	— —	— —	0 (15)	— —
Tony	— —	— —	— —	3 (16)	13 (24)
Transcendent	— —	— —	— —	0 (16)	4 (12)
Virginia crab	— —	— —	0 (16)	5 (15)	11 (24)
Wealthy	5 (16)	— —	2 (11)	— —	— —
Winesap	— —	— —	— —	8 (16)	— —
Winter St. Lawrence	— —	— —	— —	81 (16)	81 (12)
Wolf River	— —	— —	— —	75 (4)	— —
Yellow Transparent	46 (47)	32 (24)	— —	— —	— —
160 (stock number)	— —	— —	10 (10)	— —	— —

* Roots budded to various scions.

Of those tested, 11 proved to be quite susceptible, 11 partially so, and 7 were resistant, while the data obtained on the remaining 11 were deemed insufficient to warrant an evaluation.

In an experiment on the effect of depth of planting on incidence of crown rot there was no significant difference in the amount of rot that developed when the trees were planted with the union 4 inches above the ground line, at the ground line, and 4 inches below it.

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RESISTANCE OF APPLE SEEDLINGS TO SCAB[1]

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The orchardists in Nova Scotia, as in many parts of the continent, suffer partial crop losses annually from the fungus disease known as apple scab (*Venturia inaequalis*). Varieties of apples now in production have been selected for their hardiness, quality, and yield, but little apparent progress has been made in obtaining varieties resistant to scab.

Many of the leading commercial varieties, as McIntosh, Delicious, Gravenstein, Wagener, Baldwin, and Stark are susceptible to scab and require a consistent fungicide treatment to protect them from this disease. Varieties such as Golden Russet, Ribston, and Cox Orange Pippin are less susceptible. Some resistance has been shown by the varieties Blenheim, Orange Pippin, and Yellow Transparent but the latter variety is of little use as a fruit for export. Among the varieties grown at the Dominion Experimental Station, Kentville, N.S., and observed as resistant to scab are Red Winter Reinette and Belle de Boskoop. These two apples differ considerably. The Boskoop resembles the Blenheim in colour and season but is poorer in quality, and, being a triploid, is an unsatisfactory parent. The Red Winter Reinette is a smaller apple, well coloured, a good keeper, and has fair quality; being a diploid, it is a useful parent in a breeding program.

During the past 10 years a collection of approximately 30,000 apple seedlings of known varietal parentage has been accumulated at the Station under the direction of the junior author. These have been planted in nurseries and allowed to develop for 5 or 6 years without fungicide protection. Observations have been made on growth, vigour, disease resistance, etc., of these seedlings. In their early life the foliage reaction to scab has been the main disease observation. Some records have been made on the reaction of the fruit to scab but the mass of seedlings are not yet in production.

It is the purpose of this paper to present a summary of the observations on foliage scab of those seedlings which have been under observation for at least four years, during which time the disease was quite prevalent. No attempt at artificial inoculation was made. The data secured are based entirely on natural infection by the fungus in the nurseries. Studies on the strains of the fungus present and the effect of the resistant host on the fungus are not dealt with in this paper.

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MATERIALS AND METHODS

Source of Seedlings

The seedlings were obtained from two sources:

(a) Known crosses were made using varieties with desirable characters. The trees were tented in the "pink stage" and immediately before bloom all buds were removed except two lateral buds in each cluster that were emasculated. The pollen for the crosses was secured by removing anthers from unopened buds, and maturing in sunlight. Pollination was performed by dipping the receptive stigmas into a metal box containing the pollen. Individual branches were used for each cross. The checks emasculated that were not pollinated set no fruit.

(b) The second source of material was from pollination studies where emasculation was not practised. A limb unit method was used and 10 replications were made of each cross on separate trees. At the late pink stage of the bloom each limb was bagged with cheese cloth to prevent cross pollination. At the full bloom period the centre flowers were removed, and those remaining in the cluster were hand pollinated. The pollen was applied to the stigmas with a camel's hair brush and alcohol was used to sterilize the brushes after each cross. It is recognized that some selfing may occur when this method is used. However, varieties which were self-pollinated gave such low sets of fruit when compared with compatible crosses that it is believed few of the selfed flowers developed seeds.

General Character of Diploid and Triploid Crosses

Reciprocal crosses were made using diploid and triploid varieties. In addition these have been selfed. A summary of the fruit set, seed germination, and seedling growth of the majority of crosses, grouped according to the chromosome number of the parents, is given in Table 1.

The percentage of fruit set was much higher in the diploid × diploid, and in the triploid × diploid crosses than in the other groups. The relatively high set of 3.7% for selfed triploids is explained by the self-fruitfulness of the varieties Baldwin and Rhode Island Greening which were included in this summary. It is interesting to note that all diploid crosses had a higher seed content per fruit than those where triploids were the female parents.

Seed germination records were taken each year. The results for 1933 only are given in Table 1. The seed from diploid × diploid and diploid selfed groups has consistently germinated better than that from triploid crosses.

Seedlings were grown for one year in the seed bed and then transplanted to a permanent location. In the seed bed it was apparent that seedlings of the diploid × diploid crosses or diploid selfed were more vigorous and uniform than the seedlings of the other groups. Seedlings from the triploid crosses usually lacked vigour, very few have grown as well as many of the diploid seedlings. These few vigorous plants from the triploid crosses maintained their vigour in permanent location; no determinations have been made of their chromosome numbers.

Many of the seedlings from triploid crosses winter killed or died soon after permanent planting. After 2 years the average height of the triploid

TABLE 1.—SET, GERMINATION, AND GROWTH OF SEED AND SEEDLINGS

Type of cross	Percentage fruit set	Average no. seeds per apple	Germination*	Stand†	Height of seedlings†
	%		%	%	Feet
Diploid × diploid	14.60	7.6	82.3	97.6	5
Diploid × triploid	2.00	5.9	28.7	26.4	4
Triploid × diploid	17.50	3.4	22.4	18.7	2
Triploid × triploid	2.90	3.2	2.6	34.7	2
Diploid self	1.70	4.4	64.9	92.1	5
Triploid self	3.70	3.1	17.8	31.2	—

* 1933 Results.
† Records taken after 2 years in permanent location. Plants set out as 1 year seedlings.

crosses was less than that of the diploids. Since seed content and germination of the triploid crosses were reduced, and since the stand and the vigour of the resulting triploid seedlings were also reduced these crosses have produced few plants for the determination of scab resistance. From the plant breeder's standpoint triploid varieties of apples have proved unsatisfactory as male and female parents.

In addition to the variations in seedling vigour mentioned above there has been an appreciable difference in growth of the plants due to the presence of scab. Seedlings from resistant parents, as Red Winter Reinette, produced an average of 18 inches growth the first year. Many seedlings from susceptible parents, as McIntosh and Delicious, were unable to make more than 4 to 6 inches growth in the same period due to severe infestations of scab on the foliage. This effect continued in the permanent planting until fungicide sprays were used.

Where a cross had been made between a resistant and a susceptible variety, the resistant variety had an effect on the resistance of the progeny. For example, in the Red Winter Reinette × McIntosh cross, although scab susceptible individuals have appeared, in no case has the scab been severe enough to defoliate the trees or stunt seedling growth.

No estimate of hereditary vigour has been possible, due to the dwarfing of the seedlings by scab.

Methods of Disease Observation

The observations on foliage scab have been made during July and August of each year. The system used in recording the disease was as follows:

1. No scab present.
2. Scab spots isolated or distinctly separate.
3. and 4. (Not used in this classification.)
5. Scab very diffuse, covering large areas.
6. Scab spots killed out; brown spots or flecks.

Following each number or combination of numbers denoting the presence of scab was a letter indicating the percentage ranges:

A—less than 10% of the foliage affected.

B—10 to 50% of the foliage affected.

C—more than 50% of the foliage affected.

A numerical system was also used to record scab on the fruit as follows:

0—No scab.

1—Few small spots, pronounced cork layer.

2—(Not used in this classification.)

3—Small to medium scattered spots.

4—Spots one-half inch or more in diameter; no normal cracking of fruit.

5—Large active spots, coalescing; fruit cracking.

These methods of classification have been found quite satisfactory for rating the scab reactions of apple varieties and seedling trees. By giving each rating a numerical value, it has been possible to get an average rating for the period under observation and to reduce the seedlings into the four groups:

Susceptible (S), slightly susceptible (SS), slightly resistant (SR) and resistant (R) as given in Tables 2 and 3.

Varietal susceptibility of Seedling Parents

Observations on the scab susceptibility of standard varieties were based largely on fruit lesions as it has not been economically practicable to allow a variety orchard to go without fungicide protection. A summary of the scab observations on the standard varieties represented as parents among the seedlings reported in this paper is given in Table 2. It will be noticed that the preponderance of commercial varieties is in the two susceptible groups.

TABLE 2.—REACTION TO SCAB OF SEEDLING PARENTS

Susceptible	Slightly susceptible	Slightly resistant	Resistant
Baldwin	Beauty of Bath	Adams Pearmain	Red Winter Reinette
Gravenstein*	Ben Davis	Cox Orange	
Lobo	Crimson Beauty	Deacon Jones	
McIntosh	Evangeline	Early Williams	
Red Delicious	Golden Delicious	English Russet	
Rome Beauty	Hubbardson	Golden Russet	
Wagener	Jonathan	Grimes Golden	
	Northern Spy	Mother	
	Red Astrachan	Opalescent	
	Tompkins King*	Yellow Transparent	
	Worcester Pearmain	York Imperial	
	Yellow Bellflower		

* Triploid varieties.

Foliage Scab of Seedlings

Rather than enter into a detailed discussion of the individual crosses and their reaction to foliage scab, the seedlings are classified in Table 3, according to susceptibility. This classification is limited to those crosses in which there were 50 or more seedlings. The figures in parentheses following the variety name (Table 3) indicate the number of years in which this cross was made. All replicate crosses were totalled and the figures represent the percentage of seedlings in each of the 4 classes. The right-hand column gives the total number of seedlings in each cross.

TABLE 3—SEEDLING SUSCEPTIBILITY BY CROSSES

—	S	SS	SR	R	Total
Baldwin					
× Cox Orange (4)	9.9	26.7	42.5	20.8	101
× Northern Spy (3)	14.3	15.8	47.6	22.2	63
Ben Davis					
× Adams Pearmain	70.3	26.6	3.1	0.0	64
× Cox Orange	72.0	18.6	9.3	0.0	75
× Crimson Beauty	47.7	38.9	13.3	0.0	113
× Deacon Jones (2)	36.9	33.7	29.3	0.0	160
× Delicious (2)	72.6	21.6	5.8	0.0	51
× Golden Russet	54.5	27.2	16.7	1.5	132
× Opalescent	78.4	19.8	1.8	0.0	111
× Red Astrachan	60.9	33.3	4.3	1.4	69
× Red Spy	56.8	34.9	7.2	0.0	83
× Wagener	81.1	14.5	4.3	0.0	69
× Yellow Bellflower	39.3	45.9	14.7	0.0	61
Cox Orange					
× Baldwin (3)	28.5	42.8	28.5	0.0	70
× Deacon Jones (2)	44.0	52.0	4.0	0.0	50
× Delicious	43.7	45.4	10.9	0.0	320
× Early Williams	43.2	42.4	14.4	0.0	132
× Golden Russet (4)	38.8	36.8	22.3	2.1	1187
× Gravenstein (3)	33.0	44.8	21.2	0.9	203
× King (3)	32.0	34.7	32.0	1.3	75
× Lobo	38.6	40.5	19.6	1.2	158
× McIntosh (4)	51.8	35.8	12.2	0.1	664
× Red Astrachan	24.0	56.0	20.0	0.0	50
× Red Spy	33.8	44.1	19.1	2.9	68
× Red Rome Beauty	49.2	30.7	18.5	1.5	65
× Wagener (4)	52.7	42.3	4.8	0.1	690
× York Imperial	34.7	41.1	23.0	1.1	265
× Self (3)	37.2	32.1	28.1	2.5	199
Open pollinated	42.3	28.5	27.7	1.4	137
Deacon Jones					
× Beauty of Bath	52.4	29.5	14.7	3.3	61
× Crimson Beauty	40.4	42.2	17.4	0.0	109
× Golden Delicious	73.0	23.8	3.1	0.0	63
× Wagener	76.7	23.2	0.0	0.0	56
× Yellow Transparent (2)	12.8	47.7	39.4	0.0	109
× York Imperial	62.5	20.2	6.7	10.5	104
Open pollinated (2)	47.0	39.9	12.9	0.2	394
Delicious					
× Ben Davis	88.8	11.1	0.0	0.0	54
× Deacon Jones	65.3	28.5	6.1	0.0	98
× Northern Spy	91.4	6.9	1.7	0.0	58
× Yellow Transparent	55.9	39.3	4.7	0.0	84
Open pollinated	71.9	22.5	4.5	1.1	89
Golden Russet					
× Baldwin (2)	33.9	29.0	35.4	1.6	62
× Cox Orange (3)	57.3	31.3	10.8	0.5	543
× Gravenstein (3)	15.1	50.0	33.3	1.5	66
× McIntosh (3)	42.5	36.1	20.1	1.2	342
Gravenstein					
× Wagener (4)	4.7	14.1	57.7	23.5	85
McIntosh					
× Ben Davis	91.4	8.5	0.0	0.0	70
× Cox Orange (2)	38.3	43.2	18.5	0.0	81

TABLE 3.—SEEDLING SUSCEPTIBILITY BY CROSSES—*Continued*

——	S	SS	SR	R	Total
McIntosh—Concluded					
× Deacon Jones	63.8	30.3	5.8	0.0	221
× Delicious (2)	81.7	17.3	1.0	0.0	98
× English Russet	87.2	11.3	1.4	0.0	71
× Golden Russet	81.0	17.4	1.5	0.0	63
× Hubbardson	46.0	32.4	20.2	1.3	74
× Jonathan	75.5	22.6	1.8	0.0	53
× Opalescent (2)	75.3	24.6	0.0	0.0	73
× Red Spy	91.3	8.7	0.0	0.0	104
× Red Winter Reinette	22.8	52.4	24.2	0.5	360
× Worcester Pearmain (2)	19.7	56.0	24.2	0.0	66
Open pollinated	46.5	40.7	12.7	0.0	535
Mother					
× Ben Davis	59.1	30.7	10.1	0.0	218
× Crimson Beauty	33.3	50.8	15.8	0.0	63
× Deacon Jones (2)	35.1	41.4	21.6	1.8	111
× Delicious	68.3	22.2	8.3	1.1	180
× Early Williams	57.5	29.9	11.5	1.1	87
× Golden Russet	41.1	39.3	19.6	0.0	56
× Grimes Golden	66.7	19.0	12.7	1.5	63
× Lobo	75.7	17.0	6.8	0.6	147
× Opalescent	58.7	31.2	9.5	0.5	189
× Red Astrachan	74.0	23.9	2.1	0.0	142
× Red Rome Beauty (2)	46.1	39.0	14.9	0.0	141
× Worcester Pearmain	18.0	54.0	28.0	0.0	50
× Yellow Bellflower	60.2	30.1	7.5	2.1	93
× Yellow Transparent	15.9	42.6	38.3	3.1	94
× York Imperial	35.4	43.3	19.7	1.5	127
Opalescent					
× Yellow Transparent	27.7	34.7	37.5	0.0	72
Red Rome Beauty					
× Ben Davis (2)	83.7	15.2	1.1	0.0	92
× Deacon Jones (2)	50.4	29.6	19.2	0.8	125
× Delicious (2)	77.9	20.6	1.4	0.0	68
× Early Russet	85.7	14.3	0.0	0.0	70
× Red Spy	84.1	15.9	0.0	0.0	63
Open pollinated	56.9	32.7	10.0	0.3	309
Red Winter Reinette					
× Ben Davis	25.5	47.0	25.5	1.9	153
× Cox Orange (2)	22.4	37.1	40.5	0.0	116
× Delicious	21.7	37.2	40.7	0.3	258
× Deacon Jones	28.7	42.1	28.1	1.1	171
× Jonathan	25.4	60.1	14.5	0.0	55
× McIntosh	43.4	40.2	16.4	0.0	279
× Opalescent (2)	32.0	45.8	21.8	0.3	275
× Red Astrachan	28.5	45.4	24.6	1.3	77
× Red Rome Beauty	33.7	48.9	17.4	0.0	92
× Red Spy	20.6	46.8	31.7	0.8	126
× Wagener	68.0	28.2	3.8	0.0	78
× Yellow Transparent	5.4	32.7	54.5	7.3	[illegible]5
Open pollinated	36.4	36.6	26.1	0.9	10[illegible]
Spy, Northern					
× Baldwin (3)	36.2	51.7	10.3	1.7	58
× Ben Davis (3)	62.9	29.4	7.3	0.3	1559
× Cox Orange (3)	34.9	37.1	26.9	1.1	1998
× Golden Russet (3)	54.9	31.9	13.1	0.1	856
× King (3)	35.4	40.2	21.9	2.4	82
× Self (2)	50.8	33.3	12.3	3.5	57

TABLE 3.—SEEDLING SUSCEPTIBILITY BY CROSSES—*Concluded*

—	S	SS	SR	R	Total
Spy, Red					
× Deacon Jones (2)	38.9	45.5	15.5	0.0	77
× McIntosh	60.2	33.3	5.3	1.1	93
× Red Rome Beauty (2)	72.9	23.6	3.4	0.0	144
× Red Winter Reinette	29.2	50.6	20.2	0.0	89
Wealthy					
× Deacon Jones	22.0	44.1	33.8	0.0	68
Yellow Bellflower					
× Red Winter Reinette	17.1	52.8	30.0	0.0	70

Table 3 presents many interesting comparisons on the behaviour of varieties as male or female parents. Previous mention has been made of the behaviour of triploids when used as female parents and the small number of seedlings obtained from such crosses. The varieties Baldwin and Gravenstein, when used as female parents for several successive years were the only triploids which produced a sufficient number of seedlings to enable their inclusion in this table. The triploid variety King is represented only as a male parent in Table 3. All other varieties in this table are believed to be diploids.

The apparent resistance of the Baldwin and Gravenstein seedlings requires some explanation. Reference to the height of seedlings, Table 1, shows that the triploid seedlings were less than half the height of diploids. These seedlings lacked vigour. Their leaves were small and frequently late in developing. Their apparent resistance to scab was probably due to avoiding infection because of lateness of spring growth and scarcity of foliage. Many of these seedlings were removed after the fourth year of scab observation on account of weak or undesirable growth characters. A few triploid seedlings have been retained in the planting for fruiting characters but the majority of these fall in the susceptible colum in Table 3. When triploids were used as male parents on diploid varieties the dwarfing effect was not as evident and there was less apparent resistance to scab than was encountered among the seedlings from triploid female parents. Triploid varieties of apples have been very unsatisfactory in this study. The low yield of seed, poor seed germination, and small stand of seedlings have made the triploid varieties of apples of little value for breeding purposes. The inclusion in Table 3 of the few crosses with triploid parents was done to emphasize the difficulties encountered, and point out the undesirability of triploid apple seedlings in scab resistance observations.

Diploid varieties have responded very differently from the triploids. In yield of seed, seed germination, and stand of seedlings they have been most satisfactory. In the seedling stage many were dwarfed temporarily from the effects of scab on the foliage. The seedlings from McIntosh, Delicious, and Rome Beauty were very susceptible to scab in the seed bed. This effect is still shown in Table 3, where it will be observed that approximately 90% of the seedlings of these 3 varieties fall in the susceptible and

slightly susceptible columns. Scab susceptibility appears to be a dominant factor in these varieties.

In contrast to the extremely susceptible varieties are those more resistant. The 3 varieties Red Winter Reinette, Golden Russet, and Cox Orange have over 25% of their seedlings classified in the slightly resistant and resistant columns of Table 3. The percentages of these seedlings susceptible to scab are much lower than those of the seedlings of the 3 susceptible varieties mentioned in the preceding paragraph.

If the data given in Table 3 are placed in 2 columns instead of 4 it will be readily seen that all diploid seedlings with the exception of the Red Winter Reinette × Yellow Transparent cross, have over half the seedlings in the scab susceptible groups. Such a grouping would indicate that resistance to scab is probably a recessive character in the diploid apple varieties used in this project.

With the exception of Delicious × Yellow Transparent, all other crosses with Yellow Transparent as a male parent have given over 37% of the seedlings showing a degree of resistance. The early blooming date of this variety made it difficult to obtain successfully crosses with Yellow Transparent as a female parent. A further study on progeny of this variety from the standpoint of scab susceptibility would appear desirable.

There are a few crosses with their reciprocals represented in Table 3. The slightly susceptible Ben Davis × the susceptible Delicious has given over 94% of all seedlings in the two scab susceptible classes. Practically the same condition is found with McIntosh × Red Spy and Rome Beauty × Red Spy and their reciprocals. In these crosses resistance appears to be recessive. When two slightly resistant parents, Cox Orange and Golden Russet, are crossed a larger proportion of the seedlings fall in the 2 resistant classes. Resistance to scab is present in these varieties but must be considered recessive on the evidence obtained. When the resistant Red Winter Reinette was used in crosses with the susceptible varieties McIntosh and Red Spy a still higher proportion of slightly resistant and resistant seedlings were obtained. Red Winter Reinette appears to carry more resistance than any of the other varieties but the factor for resistance to scab is apparently recessive.

From the data presented in Table 3 it is apparent that susceptibility appears more frequently than resistance, and is a dominant character of many of the best quality varieties. Complete immunity to scab has not been obtained in any of the seedlings from standard varieties. The nearest approach to immunity has been observed locally in seedlings of *Pyrus niedwetzkyana*.

SUMMARY

1. The progeny of over 100 apple crosses has been studied for a period of at least four years and the degree of susceptibility of the seedlings to apple scab (*Venturia inaequalis*) has been recorded.

2. Evidence is presented to indicate that resistance to apple scab appears recessive to susceptibility.

3. Triploid varieties of apples have been unsatisfactory from the breeders standpoint on account of the low seed content, poor germination,

and low vigour of the seedlings. Their apparent resistance is believed to be due to avoiding infection because of delayed foliation rather than true resistance.

4. In the early stages of growth low apparent vigour in scab-susceptible seedlings has been due to severe infections of the disease.

5. The variety Red Winter Reinette has been the most resistant parent used in these crosses. The varieties Cox Orange and Golden Russet have given good proportions of resistant progeny.

6. Mention is made of the possibilities of resistance from crosses using the variety Yellow Transparent.

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PROTEIN IN POULTRY NUTRITION[1]

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INTRODUCTION

Both from an economic and a physiological standpoint the protein fraction of the poultry ration is of major importance. Growing birds require large quantities of protein for the formation of muscle tissue, skin, blood solids, feathers and toe nails. Laying hens, although their requirements for growth are less, must have sufficient to meet the heavy demands of egg production. Moreover, every living cell in the body contains vital structures which require protein for their formation and maintenance. For all these needs the bird is dependent on a continuous supply of suitable protein from the diet since apparently it possesses little capacity for accumulating a reserve.

Workers in the field of nutrition are familiar with the fact that the proteins are built up of units of amino acids. Also familiar is the concept of the enzymatic breakdown of the complex protein molecules to their constituent amino acids during the process of digestion and the transport of these amino acids to various parts of the body where they are utilized for the formation of protein tissue. However, it is worth emphasizing that the amino acid requirement of an animal or bird is not merely quantitative but includes a demand for adequate amounts of several specific amino acids. It is evident that the ability of a protein to satisfy this demand determines its feeding value.

The amino acids which have been identified as occurring in natural proteins are listed below. On the basis of feeding experiments with rats, ten of these are classed as "nutritionally essential" i.e., they cannot be synthesized in the body of the rat and must be supplied through the nutriment to maintain normal growth. While it does not necessarily follow that the amino acid requirement of poultry is analogous to that of the rat, the experimental evidence available indicates that the requirement of poultry is at least as specific.

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Nutritionally non-essential	*Nutritionally essential*
Alanine	Arginine
Aspartic acid	Histidine
Citrulline	Isoleucine
Cystine	Leucine
Glutamic acid	Lysine
Glycine	Methionine
Hydroxy glutamic acid	Phenylalanine
Hydroxy proline	Threonine
Norleucine	Tryptophane
Proline	Valine
Serine	
Tyrosine	

In reviewing this field of poultry research, the author was impressed by the large volume of literature on the subject but encountered great difficulty in envaluating much of the work owing to the great diversity of conditions under which the experiments of the various investigators were carried out. Obviously, for example, to say that, during early rapid growth, the chick requires a level of 18 to 20% protein in its diet does not convey a very complete picture of the problems involved in satisfying this requirement. The source of that protein, any pretreatment to which it may have been subjected and its digestibility must be considered. Lack of adequate knowledge in regard to the amino acid requirement of poultry and the amino acid composition of protein feeds has handicapped workers in this field. Also it should be remembered that prior to about 1932 the importance of riboflavin in poultry rations for growth and hatchability was not generally recognized, and much of the early work on proteins may have been complicated by the ability of the protein supplement to supply this vitamin to the diet. These and other considerations will be mentioned later in this review.

Heuser (114) has published an excellent survey on the protein problem in poultry nutrition and Almquist (19) has discussed the amino acid requirements of chicks. The author has depended on these publications for guidance during the preparation of a considerable portion of this review.

1. PROTEIN REQUIREMENT FOR GROWTH

The protein requirement of the chick is most commonly measured by rate of gain in weight, but other factors such as efficiency of feed utilization, age of sexual maturity, feathering and general health of the birds are also considered.

Since the chick is a rapidly growing animal, doubling its birth weight in about 10 days, it is to be expected that the protein requirement of the chick during the early stages of its growth would be comparatively high. The results obtained by investigators in this field confirm this conclusion. Mussehl (170), St. John *et al.* (210), Milne (161), Roberts and Carrick (201), Ackerson *et al.* (5), and Tomhave (250) observed that growth was stimulated during the first few weeks following hatching by protein levels up to 20% or over. Swift, *et al.* (234) fed various levels of protein to White Leghorn chicks

from the age of 2 weeks to 18 weeks and found that the greatest gains in weight were obtained with a level of approximately 21%. Winter *et al.* (266), in a study of the protein requirement of White Leghorn pullets between 6 weeks of age and the onset of laying, found that a drastic reduction of protein, especially at an early age, retarded growth and lowered the intensity of subsequent egg production.

The influence of the protein level of the diet, from hatching time to 20 weeks or longer, has been studied by many workers, the majority of whom agree that the early rate of growth of chicks increases with the protein level of the ration to an optimum of approximately 18 to 20% and that this level can be decreased as the birds mature.

Heuser and Norris (111) from their investigations at Cornell, concluded that the ration should contain approximately 20% of protein for the first 6 to 8 weeks, 18% from then on up to 12 to 14 weeks, and 15 to 16% for the rest of the growing period. Their data also showed that depressed growth in the earlier periods, provided it is not too severe, can be compensated later on by more rapid growth if the protein level becomes adequate. This latter observation was confirmed by the work of Carver *et al.* (64). The results of all trials at Cornell were summarized by Heuser (114), who stated that to obtain early rapid growth the ration should contain approximately 20% protein during the first month, and that this can be reduced 2% for each succeeding month to a minimum of not less than 15%.

The conclusions reached at Cornell were well substantiated at the Delaware Station by Tomhave (251). Using White Leghorn pullets and varying the protein level of the rations by changing the proportions of meat scrap and dried buttermilk, Tomhave made the following observations:

1. Lowering the protein level below 18% previous to 8 weeks of age resulted in lower weight of pullets at 20 weeks.

2. A protein level of 14 to 16% in the growing ration did not develop chicks as rapidly as they are capable of developing in the early growing period.

3. After pullets reached 8 to 10 weeks of age a 16% level of protein produced gains practically equal to a ration containing 18%.

4. During the first 8 weeks of the growing period an 18% level of protein produced a pound of gain on less feed than a 16 or 14% level.

5. The lowest feed requirement to make a pound of gain occurred when the growing ration contained 18% protein for the first 8 weeks and 16% from the 9th to at least the 16th week of the growing period.

Carver *et al.* (64) on the basis ofexperiments in which they adjusted the protein levels of their rations by varying the proportions of Alaska herring meal and dried whey, recommended that the chick diet should contain approximately a level of 17% high quality protein from 1 to 6 weeks, 15% from 7 to 12 weeks, and 13% from 13 weeks to maturity.

In experiments conducted by the United States Department of Agriculture (Hammond *et al.* (94)), groups of crossbred male chicks were fed for their full growing period on diets containing protein levels of 13 to 25% by increments of 2%. A percentage of 21% was found to be near the optimum for efficiency of food utilization. Titus (245) in reference to these results stated that although the optimum protein intake is from a physiological standpoint about 21%, from the standpoint of economy it may be only 18 or 19% because the efficiency of feed utilization for growth is only slightly less at these levels than it is at the 21% level. He recommended the feeding of a diet which contains 20 to 21% protein until the chickens are about 12 weeks old and than to a gradual decrease in protein content to about 16 or 17% by the time the pullets are ready to lay.

Further confirmation that a lower level of protein is adequate for the advanced growing period was provided by Dearstyne *et al.* (71) who found that 15% protein in the mash (grain fed in addition) was satisfactory for Rhode Island Reds from the time they weighed 1.5 to 2 pounds until production reached a level of 25 eggs per 100 birds per week.

It was observed by many workers (McConachie (157), Norris and Heuser (175), Swift *et al.* (234), Carver *et al.* (64), Hammond *et al.* (94)) that when growing chickens were fed varying amounts of protein, those fed high levels used the protein less efficiently and the feed as a whole more efficiently than chickens fed low levels of protein. It has been mentioned previously that depressed growth in the earlier periods due to relatively low level of protein intake may be compensated for later on if the protein level becomes adequate. Consequently, both low and high protein groups may eventually reach the same weight at maturity, and it would appear that little advantage would be gained by feeding a high protein level when the chicks are carried through their full growing period. However, it is quite possible that the more efficient utilization of high protein rations would more than compensate for their higher cost provided the price differential between the low and high protein ration was not too large. This is an important consideration from the standpoint of economy of feeding and it is unfortunate that in most of the feeding experiments recorded in the literature this factor has apparently not been considered.

There is conflicting evidence regarding the influence of the protein level of the ration on the age at which pullets begin to lay. Carver *et al.* (62) claimed that the rate of sexual maturity was retarded by a ration containing 12% protein and Carver *et al.* (64) noted that White Leghorn pullets fed rations containing 19% protein reached sexual maturity a few days earlier than those fed on rations containing 13%. However, the results obtained by other workers (Winter *et al.* (266), Dearstyne *et al.* (71), Byerly *et al.* (49), Morris (168), Tepper *et al.* (238), Heuser and Norris (112), Callenbach *et al.* (55)) indicated that the rate of sexual maturity was not influenced to any marked degree by the protein content of the diet. In view of this, it seems safe to conclude that the rate of sexual maturity cannot be hastened materially by a high level of protein in the diet and is only influenced by a level low enough to seriously delay growth.

As mentioned before, feather development is a factor to be considered in the protein requirement of the chick. Since feathers are composed chiefly of protein it is probable that poor feathering would result from an inadequate supply of protein in the diet. Tomhave (251) showed that when the protein level of the diet was reduced below 18% previous to 8 weeks, bare breasts occurred in White Leghorn pullets. Gericke and Platt (82), Ackerson *et al.* (5), and McConachie *et al.* (157) all reported feather development to improve proportionally with increased amounts of protein in the ration. The latter workers, using Barred Plymouth Rocks, found that this relationship was more marked in the cockerels than in the pullets. They also noted a high incidence of "crow's head" among the low protein diets. Margolf (152) noticed feather pulling, tail picking, and cannibalism developing among chicks on low protein diets as early as the second and third weeks. It is particularly interesting that McConachie *et al.* (157) observed that both high and low protein diets tended to destroy the barring and to change the contour and texture of the feathers. These effects were particularly evident on the high protein diets and with pullets. Possibly, the disturbance of normal barring was related to the tyrosine or phenylalanine intake of the birds.

As already indicated, there is general agreement that 18 to 20% is the optimum level of protein during the first few weeks of growth. A few workers, however, have found a higher level to be satisfactory. McConachie *et al.* (157) using a protein supplement of fish meal and buttermilk powder found a 25% level of protein to be optimum for growth during the first 6 weeks. Milne (161) obtained the most rapid and economical gains during the early growth period with a level of 23.3% Both Milne and McConachie *et al.* reported detrimental effects on growth rate when the protein level of the diet was raised to 30% or over and the latter found a high mortality among chicks at a 35% level. It appears, however, that the highest levels most generally recommended (18 to 21%) can be fed without detrimental effects. Carver *et al.* (62) conducted a post-mortem examination of chicks fed from hatching to 38 weeks on a ration containing 18.2% protein and found no injury to the heart, liver, spleen and kidneys of the birds.

The influence of the breed on protein requirement has received little study. Most workers have used White Leghorn chicks as experimental birds. There is some evidence, however, that the requirement for the heavier breed chick is somewhat higher. Investigations carried out in Australia (20) showed that heavy breeds such as Light Sussex and Austrolorp made the most satisfactory gains when a high protein ration (18 to 19%) was carried to 9 weeks of age. White Leghorns, on the other hand, did equally well when the protein level was reduced to 14 or 15% at 6 weeks.

Mitchell *et al.* (163, 165) studied growth changes in White Plymouth Rock and White Leghorn chicks by chemical analyses of birds slaughtered at regular intervals. Using the results of these analyses, they compiled a table of tentative feeding standards, part of which is given in Table 1. The values for maintenance were obtained by Mitchell and cooperators by reference to the work of Ackerson *et al.* (1) on the endogenous metabolism of hens and capons.

TABLE 1.—ESTIMATED DAILY CRUDE PROTEIN REQUIREMENT OF GROWING WHITE LEGHORN AND WHITE PLYMOUTH ROCK CHICKENS[1]

Body Wt.	White Leghorns							
	Cockerels				Pullets			
	Maintenance	Growth	Total[2]	Dig. protein[3]	Maintenance	Growth	Total	Dig. protein
lb.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
0.5	0.5	2.2	2.7	5.4	0.5	1.7	2.2	4.4
1	1.0	2.5	3.5	7.0	1.0	2.2	3.2	6.4
1.5	1.5	2.6	4.1	8.2	1.5	2.3	3.8	7.6
2	2.0	2.6	4.6	9.2	2.0	2.1	4.1	8.2
3	2.8	2.5	5.3	10.6	2.8	1.0	3.8	7.6
4	3.6	2.1	5.7	11.4	1.4	0.4	1.8	3.6
5	2.5	2.0	4.5	9.0				

Body Wt.	White Plymouth Rocks							
	Cockerels				Pullets			
	Maintenance	Growth	Total[2]	Dig. protein[3]	Maintenance	Growth	Total	Dig. protein
lb.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
0.5	0.5	1.6	2.1	4.2	0.5	1.5	2.0	4.0
1.5	1.6	3 7	5.3	10.6	1.6	3.7	5.3	10.6
2.5	2.5	6.2	8.7	17.4	2.5	3.0	5.5	11.0
3.5	3.5	4.3	7.8	15.6	3.5	3.4	6.9	13.8
4.5	4.5	4.3	8.8	17.6	4.4	2.7	7.1	14.2
5.5	5.4	3.7	9.1	18.2	4.3	1.3	5.6	11.2

[1] Data of Mitchell, Card and Hamilton and Ackerson, Blish and Mussehl.
[2] Total minimum requirement of protein.
[3] Assuming a biological value of 50.

The protein requirement for most rapid and economical gains during the full growing period may be summarized as follows. During the first 4 to 6 weeks when the most rapid growth is taking place, the diet should contain at least 20% of protein of good quality. From the end of this period until the end of the growing period the level may be reduced gradually to a minimum of approximately 15%. Although a very high protein content of the diet (30% or above) results in high mortality among chicks, the highest levels most generally recommended can be fed without harm.

The considerable variation shown in the results obtained by different investigators can probably be attributed to variations in climatic condition, management and strains or breeds of birds used. Moreover, there is no doubt that the optimum level varies with the biological value of the protein. It should also be remembered that changes in other components as well as the protein are involved when the protein level is adjusted by changing the proportion of the concentrate. Consequently, one cannot always be certain that the observed results can be attributed solely to a change in the protein level of the ration.

2. PROTEIN REQUIREMENT FOR EGG PRODUCTION

The value of a ration for laying hens should be based on a consideration of egg production, egg size, body weight, efficiency of food utilization, and general health and well being of the birds.

The average hen's egg contains approximately 14.0% protein which, according to Wilcox (261) is practically all drawn directly from the nitrogen of the food. However, Ackerson *et al.* (2), in the course of nitrogen metabolism studies with poultry found that hens laid eggs 6 to 7 days after the nitrogen intake had been reduced to a neglible amount. Apparently, there must be some labile protein stored in the hen's body which she can utilize for the production of eggs for a limited period.

Bird and Sinclair (38), in a study of the energy requirement for maintenance and egg production, found that 63% of the food which was available for egg production was utilized for this purpose, except at the start of laying when the efficiency was somewhat higher. Muller-Lenhartz and Von Wendt (169), assuming that 64% of the digestible protein is utilized, estimated that the ration of the laying hen in average production should contain 185 grams of digestible protein per kilogram of egg. With ad libitum feeding of a protein concentrate, there seems to be a tendency for the hen to adjust her protein intake to a characteristic level. Trials at the Ohio station (Kennard and Chamberlin (133)), have shown that on a free choice method of feeding (mash and grain) the hen balanced her ration at a protein level of approximately 15%. Graham (84) found that when pullets were fed ad libitum whole corn, whole oats, and mash, the variation in protein level for individual birds was very slight. Some birds laid well and gained on a 12 to 13% level, while others desired or required 14 to 15%. Where the protein requirement was high, however, egg yield was not necessarily high also. Rhodes *et al.* (196) showed that laying pullets, fed on mashes, low, medium and high in protein, had a tendency to adjust the level of protein intake to a common level by varying the relative amounts of mash and grain consumed.

Reports from several experiment stations indicated that a medium level of protein in the diet promoted satisfactory egg production. From Cornell, Heuser (113) reported that probably a 16% protein level in the ration is near the optimum for laying hens. With casein as a supplementary protein, 16% protein gave satisfactory egg production, body weight and egg size, 14% protein gave satisfactory egg production but did not maintain body weight or optimum egg size, and 12% protein proved completely unsatisfactory. This work was largely substantiated at the Washington station by Heiman *et al.* (106) who concluded that a laying ration fed at a level of 15% protein from adequate sources (plant and animal) can safely be recommended for satisfactory egg production. These workers found that a 12 to 13% level of protein from plant sources alone was inadequate. Thompson (241) reported from the New Jersey station that trials with laying rations containing 10, 12, and 14 and 16% protein indicated a 14% level as the most efficient, and he concluded that a fairly high level of protein is necessary to maintain body weight and stimulate egg production.

The results of experiments conducted in Germany (Zollner (268), Weinmuller *et al.* (257), Albrecht (7), Jaeger, *et al.* (121)), supported the finding of American workers that egg production is in accordance with protein level. Zollner (268) fed White Leghorn pullets 3 levels of protein, 9.6%, 13.8%, and 18.0%, and although the high protein lot showed the highest utilization of the food protein, the medium protein lot gave the best egg yield. Zollner also noticed an apparent connection between protein supply and moulting, the latter being lighter and shorter with the higher amounts of protein. Albrecht (7) using as a protein supplement a mixture of fish meal, soyabean meal and peas, reported that a nutritive ratio of 1 : 4.38 gave maximum egg yield and that a ratio of 1 : 11.85 was totally inadequate for egg production.

Several experiments have been reported from England. Investigations by Thomas (239) in which Rhode Island Red hens were kept 13 months on high, medium and low protein intake indicated that although more eggs were produced on the high level, the medium protein level gave the lowest food cost per egg. MacDonald (145) reported that for egg production 14.2% in a mash forming one-half the total diet was as satisfactory as 20.8% provided the birds were allowed outside range. On a later study, involving N balance experiments, MacDonald (146) noted that hens could be kept in positive N balance on a diet containing 12.5% protein and that this level compared favourably with 15.4% for egg production.

The question might arise concerning the influence of the level of protein fed during the growing period on subsequent egg production. Carver *et al.* (64) fed protein levels varying from 13 to 19% during the first 22 weeks from hatching and 15.3% thereafter and found that, during the first 224 days of egg production at least, the different diets fed during the growing period had no influence on the rate of egg production. Moreover, the average initial and final albumen index (Heimand and Carver (105)) and egg weights were not influenced by the amount of protein fed in the diet of the growing pullets. Bronkhorst (43) fed growing White Leghorn pullets levels of 10, 15 and 20% meat meal with a basal ration of yellow corn and wheat by-products and noted that the age of sexual maturity and subsequent egg yield did not seem to be affected by the different levels.

There seems to be some difference of opinion regarding the effect of the protein level of the ration on egg size. Lampman (139) observed that eggs from pullets receiving plenty of protein averaged 2 oz. per dozen, heavier than eggs from pullets on medium or low protein allowance. Bronkhorst (43), whose work was mentioned above, found that the size of egg was directly dependent on the level of meat meal in the ration. Heuser (113) and Heiman *et al.* (106), using casein and fish meal respectively as protein supplements, found that egg size increased as the protein level of the ration was increased to approximately 15 to 16%. These findings, on the other hand, are in disagreement with those of several other investigators. It was reported by Parkhurst (188) that varying amounts of protein in a ration, when the minerals content remained the same, did not have any significant effect on egg size. He also noted that a complex

protein was as ineffective as a simple one in increasing egg size. Similarly Graham (86) found no relationship between egg size and type of protein concentrate fed. He compared beef scrap, tankage and fish scrap, added on an equivalent protein basis to a basal mash, and buttermilk powder of which one-half the quantity by weight was used. It would appear from the results with the tankage supplement that, at least within certain limits, protein quality was not related to egg size. Henderson (108) observed a small but significant decrease in average annual weight of pullets with increased protein level in the ration. Two different protein supplements (dried milk and meat and bone meal) were used in adjusting the protein level of the ration from 12.3 to 14.9% and both had the same effect on egg weight. It was noted that this effect did not depend on annual egg yield, the number of eggs produced per month not being influenced by the percentage protein in the diet.

The protein requirements of several breeds of laying hens have been compared by Baelum (26). A light breed, Brown Italian, required 10.5 to 11% digestible true protein. This is provided by a daily ration of 65 gr. grain with free access to a mixture containing 16% of digestible true protein. The heavier breeds, Plymouth Rock, Rhode Island Red and Sussex, required slightly more total protein and so ate more of the protein mixture. No advantage was gained by feeding more protein than was provided in this way but egg yield fell in proportion as the supply fell short of this level.

There appears to be little information on the effects of feeding excess protein to laying hens. However, Miller and Bearse (160) found that a ration containing 30% of a protein concentrate did not produce a high percentage of organic trouble and Heuser (114) stated that, in general, experience has shown that hens can tolerate a fairly high protein ration if other conditions are favourable.

Although there is general agreement among workers regarding the protein requirement for egg production, there is a great need for a standardized procedure. Large group sizes and careful randomization in the distribution of individuals among the groups is very necessary in biological work. Henderson (109) in a critical survey of several methods for testing the influence of different rations on egg production suggested that: (1) yearling hens of previously determined egg laying ability when fed the same ration should be evenly distributed among the different experimental lots; (2) production should be calculated on the basis of the average number of egg per hen per day, and moulting and known broody and "sick" periods should be deducted from the number of days in which laying is considered possible; (3) the length of testing period may be a laying year or 12-month provided that the rations to be tested have been fed at least one month prior to the beginning of the laying year; and (4) that statistical methods should be used in interpreting the results of experiments.

3. PROTEIN REQUIREMENTS FOR HATCHABILITY

The problem of the nutrition of the breeding hen is of most practical importance during the winter months when, owing to snow and adverse weather conditions, the birds must remain inside and green feed and

beneficial sunlight are not available. While the quality and quantity of the protein in the diet of the hens is no doubt of great importance for hatchability, it is difficult to evalute the available evidence since in many cases the protein supplement may make up deficiencies, not only in proteins, but in vitamins and minerals as well. It is generally agreed upon, also, that genetic inheritance has a great influence on the successful hatching of a fertile egg. This is exemplified by the observations of Patton and Rouls (186) who found that, in a group of White Leghorn pullets of the same age and fed on a diet considered adequate in all respects, the hatchability of eggs from individuals ranged from 0 to 95.6%.

A level of approximately 16% protein of good quality has been recommended for egg production, and it appears that this level of protein is also satisfactory for hatchability. It was shown by Jull (127) that heavy egg production was not detrimental to, but rather was conducive to, high hatchability. Davis (70) suggested that the most practical means of solving the protein problem for breeding hens was to feed a ration containing from 14 to 16% of protein that was supplied from both animal and vegetable sources. Byerly *et al.* (50) found no correlation between the percentage of protein in the diet and hatchability. However, later, Titus (246) stated that, if the protein content of the diet were reduced sufficiently, the hatchability of the eggs was decreased and he recommended a diet containing 16% of protein of good quality.

A report from Germany (Muller-Lenhartz and Von Wendt (169)) indicated that a ration too high in protein had a detrimental effect on fertility and hatchability and that a satisfactory ration should contain approximately 185 grams of protein per kilogram of egg.

The relative value of animal and vegetable protein for breeding hens has been the object of several investigations. Hatano (116) found that animal protein instead of vegetable protein in the ration of the cock or the hens greatly increased the number of copulations per day. Byerly *et al.* (49, 50) observed that the substitution of vegetable protein for animal protein greatly increased the incidence of chondrodystrophy and caused the occurrence of a large number of dead germs in the second week of incubation. On the other hand, investigations in the author's laboratory (189) with sunflower seed oil meal showed that the partial substitution of animal protein in the ration with this product did not lower hatchability or result in a greater incidence of chondrodystrophy. Heiman *et al.* (106) noted that supplementing a basal ration of grain and alfalfa meal with fish meal gave increased hatchability. Albrecht (7), also from Germany, reported that hatchability was best when a ration high in plant protein was fed during the laying period.

Although the reports cited above are contradictory, the weight of evidence suggests that the ration should contain a considerable proportion of animal protein. It should be noted that a ration which gives high egg production is not necessarily satisfactory for hatchability. It is usually advantageous, when compounding a hatchability ration to include a protein supplement rich in riboflavin in order to ensure an adequate supply of this vitamin in the diet.

Our present knowledge is inadequate to explain the apparent relationship between the protein in a hen's diet and the hatchability of her eggs. Titus *et al.* (244) noted that the percentage protein in the yolks was increased by the inclusion of certain protein supplements in the diet. McFarlane *et al.* (158) found no significant difference in the composition of the protein of eggs of poor hatchability and those of high hatchability as far as the total N, total amino N, tyrosine, tryptophane and cystine content were concerned. There was no evidence that the diet of the hen significantly influenced these values. An investigation by Calvery and Titus (56) along similar lines also yielded more or less negative results. Undoubtedly, the general health of the birds is an important factor affecting hatchability, and possibly, as Heuser (110) stated, "the physiological condition of the hen is the important consideration and hatchability is influenced by the various factors as they in turn affect condition."

4. AMINO ACIDS IN POULTRY NUTRITION

The 10 amino acids classified by Rose (206) as "nutritionally essential" for normal growth in the rat have been listed in the introduction to this review.

Since, in general, it has been found that the dietary requirements of birds are more complex than those of the mammals, it may be expected that the amino acid requirement of the chick will be at least as specific as that of the rat. However, up to the present time, only a few amino acids have been studied in any detail relative to their importance in poultry nutrition, namely, methionine, cystine, glycine, arginine, tryptophane and lysine. The requirement of these amino acids for growth have been established only approximately and only for the White Leghorn breed. Obviously, much work remains to be done in this field. Apparently, there is no available information in the amino acid requirement of laying and breeding hens. It has been shown that the level of protein required for egg production and hatchability is lower than that necessary to support rapid growth. However, it may be well that the amino acid requirements for these purposes differ considerably and it would seem that there is presented here another fertile field for investigation provided certain technical difficulties can be surmounted.

The most fruitful investigations into the amino acid requirement of the rat have been conducted using mixtures of pure amino acids as the sole source of protein in the diet. So far this method has not been applied to chicks owing to the expense of the procedure and the rather complex dietary requirements of the chick which makes the formulation of such a highly purified diet difficult. However, valuable information has been secured by selecting protein combinations which are very low in their content but not necessarily free of the amino acids under study. Casein has been used as the "foundation" protein in most of these studies. It is interesting to note in connection with its use, that even the most favourably supplemented acid hydrolyzed casein diets were inferior to diets containing the unhydrolyzed casein for the promotion of growth (Klose *et al.* (136); Stokstad (232)). Apparently, whole casein contains some growth factor or factors, as yet unidentified, which are destroyed during acid hydrolysis.

In the following discussion of the amino acids known to be "essential" for the chick, the sulphur-bearing amino acids, cystine and methionine, have been grouped together since they are related in their functions. Similarly, glycine and arginine have been discussed under one heading.

Methionine and Cystine

Klose and Almquist (138) established the essential nature of methionine for the growth of chicks. Using a basal diet, containing 20% arachin, 5% gelatin, 5% brewers' yeast and 0.1% 1-tryptophane, they found the addition of at least 1.0% dl-methionine was necessary for optimum growth. Neither creatine, cystine nor homocystine could replace methionine although homocystine when combined with choline was effective. However, Jukes found that, although methionine could replace choline in the diet of the rat, it did not effect choline deficiency in the chicks and turkeys (124, 125).

It has been well demonstrated that the growing rat can synthesize cystine from the sulphur of methionine (Rose and Wood (207), Beach and White (33), Brown and Lewis (45)). The chick is undoubtedly similar to the rat in this respect. Hayward and Hafner (101) found that methionine was more effective than cystine for improving the growth of chicks fed raw soybean protein. Since such protein is low in cystine and suboptimal in methionine, it would appear that methionine can successfully replace cystine in the chick diet. Briggs *et al.* (42) found that chicks on a diet containing approximately 0.6% methionine required and could utilize at least 0.3% of cystine (or its equivalent of methionine) and concluded that, in diets suboptimal in methionine, cystine could supply about one-third of the total methionine requirement of the chick.

Glycine and Arginine

The chick differs from the growing rat in possessing a much greater dietary requirement for arginine (21) and a definite requirement for glycine (10, 11, 103, 12).

Klose *et al.* (136) estimated the arginine requirement at 1% or more of the diet. Apparently the Krebs-Henseleit mechanism for arginine formation and decomposition does not operate in the chick since ornithine, urea, or a combination of these, could not replace arginine (Klose *et al.* (136)). However, Klose and Almquist (137) found that citrulline could replace arginine in the diet of chicks and concluded that the chick was capable of converting citrulline into arginine.

Almquist *et al.* (12) estimated the glycine requirement to be about 1% of the diet. Larger amounts of glycine (2% or more) may be toxic to chicks (Almquist *et al.* (10)) and heavy daily doses of glycine (4 gm. or more) have proved fatal to hens (Patton (187)). It is not known whether the chick completely lacks the ability to synthesize glycine. Almquist and Mecchi (11) found that sodium and ammonium acetates could replace glycine for chick growth. It is probable that the chick is capable of a slow synthesis of glycine, the rate of which is insufficient to supply the requirement during early rapid growth.

A deficiency of either glycine or arginine results in poor growth, a tendency to low muscle creatine, poor feather development and a typical paralysis which is related to an organic lesion in the spinal cord. Hegsted *et al.* (104) described this paralysis as characterized by poor muscular development and a high stepping stilted gait with the hocks thrust forward and the toes extended. Arginine supplement when added to a ration deficient in both arginine and glycine, had some preventative action but glycine supplement alone had none. When both were fed together, however, complete prevention was obtained. Hegsted *et al.* (104) also noted that the glycine and arginine requirement for a rapidly feathering breed (Leghorns) was greater than for a slowly feathering breed (Plymouth Rocks) and concluded that the rate of feather formation was an important factor in determining the requirement of these two amino acids, particularly in view of the high arginine and glycine content of feathers. However, Jukes and Almquist (126) pointed out that imperfect feathering is a symptom observed with dietary deficiencies in general and may not in this case necessarily indicate a special requirement of arginine and glycine for the production of feathers.

Patton and Palmer (184) found that chick embryos with chondrodystrophy contained less glycine than normal embryos, probably as a result of poorer formation of cartilaginous and bony tissue, the proteins of which are especially rich in glycine. It was noted (Patton and Palmer (184), Patton (185)) that glycine was synthesized in the developing embryo. No relationship was found, however, between the occurrence of chondrodystrophy and the glycine content of the diet (Patton (185)).

The chick is similar to the rat in that glycine and arginine are involved in the synthesis of body creatine. This is evident from the fact that chicks on arginine and glycine deficient diets show an abnormally low muscle creatine which is raised by feeding both glycine and arginine (104, 15). Moreover, creatine supplements to arginine and glycine deficient diets lead to increased growth (15).

It has been well established by Bloch and Schoenheimer (40) that the main pathway for synthesis of creatine in the rat is a reaction of glycine with the amidine group of arginine to form guanidoacetic acid, and a methylation of the latter to form creatine by a shift of the methyl group from metionine. The evidence supports the belief that, although differing in a few respects, the pathway in chicks is essentially the same. Almquist *et al.* (15) found that guanidoacetic acid, creatine and creatinine were all effective in raising muscle creatine and promoting growth with chicks fed on diets low in glycine and arginine. It would appear from this, that creatinine formation in the chick is closely related to body growth and also that creatine can be reversibly transformed into creatinine. On the basis of experimental evidence, Almquist (19) proposed the following scheme for the biological formation of creatine in the chick:

glycine + arginine → glycocyamine (+ ornithine?)
glycocyamine + methionine → creatine (+ homocysteine?)
creatine ⇆ creatinine.

It has not been proven that methionine is necessary in the above scheme. Methionine deficiency, serious enough to prevent growth, did not reduce the muscle creatine below normal (Almquist *et al.* (15)). Ornithine, if produced, could not be reformed into arginine (Klose *et al.* (136)) but methionine could possibly be replaced by a combination of the homocysteine and choline (Klose and Almquist (138)).

Other Amino Acids—Lysine, Tryptophane and Histidine

To study the requirement for lysine, Almquist and Mecchi (16) used a diet containing as the amino acid source 25% edestin, 1.0% glycine and 0.4% dl-methionine. Growth response on the addition of 1 l-(+)-lysine monohydrochloride indicated that for the highest rate of growth the diet should contain approximately 0.9% lysine.

Experiments by Almquist and Mecchi (14) indicated that the chick possesses a requirement for tryptophane. This has been estimated very approximately at 0.5% of the diet, a value which is 2.5 times the requirement suggested by Rose (206) as being adequate for the rat.

Klose *et al.* (136) observed that chicks fed on a diet low in histidine exhibited an increase in growth rate when this amino acid was supplied.

5. PROTEIN SUPPLEMENTS

The cereal basal diets which are commonly used in poultry rations and which supply the largest fraction of the protein in the diet are seriously deficient in several of the essential amino acids required by the chick. Therefore, the value of a protein supplement, as such, will depend on how well it can make good the deficiencies of the basal ration in these essential amino acids. Almquist (17) compiled amino acid data, obtained from many sources, for a large number of poultry feedstuffs. These values plus some more recent data published by Block and Bolling (28) are given in Table 2. It is obvious that this table can at best serve as only a rough guide to the amino acid composition of the various concentrates. Not only are the data very incomplete, but methods for the estimation of amino acids are still imperfect and in certain cases the results obtained by the various workers may not be strictly comparable. However, it should be realized that, although a more complete knowledge of the amino acid composition of the common poultry feeds and the amino acid requirements of poultry would greatly assist in making the most efficient use of protein supplies, such factors as palatability and digestibility will always make practical feeding trials a necessity. Moreover, in addition to contributing amino acids to the ration, protein supplements are often valuable sources of other important dietary factors, chiefly minerals and vitamins. Drastic replacement of animal protein concentrates by their vegetable counterparts may, in some instances, necessitate an addition of certain minerals in order to balance the diet. For example, Heuser *et al.* (115) found that rations in which the protein was supplied by cereals and 30% soybean meal were too low in available phosphorus to promote normal chick growth and bone development.

When the results of feeding trials are evaluated, the conditions under which the tests were conducted should be carefully considered and broad interpretations avoided. It is important to bear in mind that the composition of the basal ration used in the experiment may have a great influence on the supplementary value of the added protein concentrate. In addition, the biological value of the protein or the mineral and vitamin content of supplements of the same class, i.e. various meat products, various fish meals, etc., may differ greatly depending on their source or method of manufacture.

(a) Meat and Bone By-Products

Included under this classification are meat and blood meals, tankage, bone meal, and several other related products containing varying amounts of meat, fatty tissue, blood and bone. Data on the amino acid composition of the protein of a few meat by-products are given in Table 2. It appears that animal proteins tend to be rather low in tryptophane. It is worth noting that Mitchell and Smuts (166) found beef protein to be too low in cystine to give optimum growth in rats.

TABLE 2.—AMINO ACID COMPOSITION OF SOME PLANT AND ANIMAL PROTEINS[a]

Feedstuff	Percentage of Amino Acid in Protein						
	Arginine	Histidine	Lysine	Glycine	Methionine	Cystine	Tryptophane
Whole corn[b]	4.0	2.4	2.5	—	—	1.1	0.7
Corn gluten[b], commercial product	3.1	1.7	1.1	—	5.5	1.2	0.6
Wheat, winter, hard	2.4	0.8	7.6	—	—	1.1	0.9
Wheat bran, winter, hard	1.9	0.3	10.8	—	—	0.5	0.6
Wheat shorts, winter, hard	3.4	0.3	10.0	—	—	0.7	0.7
Wheat germ meal[b], commercial product	6.0	2.5	5.5	—	2	0.6	1.0
Cracklings	—	—	—	—	—	0.7	0.8
Sardine meal	6.5	1.2	6.8	—	4.6[*]	1.1	1.5
Whale meal	—	—	—	—	—	0.9	1.8
Menhaden meal[b]	5.9	2.4	5.7	—	3	1	1.2
Salmon meal	6.6	1.9	6.6	—	—	1.3	1.3
Tuna meal	—	—	—	—	3.6[*]	—	—
Dogfish meal	6.7	—	—	—	—	0.9	1.5
Gelatin	8.2	1.0	5.9	25.5	0.0	0.2	0.0
Hoof meal[b], commercial product	10.4	1	3.2	—	—	7.3	1.5
Tankage[b], commercial product	5.5	2.7	6.0	—	3	1	0.7
Meat scraps[b], commercial product	7.0	2.0	5.1	—	3	1.0	0.7
Casein, 85% of milk proteins	3.8	2.5	6.0	0.5	3.3	0.5	2.2
Lactalbumin, 14% of milk proteins	3.0	2.1	8.8	0.4	2.7	4.3	2.7
Milk proteins	3.6	2.4	6.3	0.5	3.2	1.0	2.3
Egg white, 38% of egg proteins	5.3	1.4	5.8	—	4.1	1.5	1.5
Egg yolk, 62% of egg proteins	7.8	1.3	5.2	1.0	—	1.5	1.3
Egg proteins	6.9	1.3	5.4	1.8	—	1.5	1.4
Yeast[b]	4.3	2.8	6.4	—	—	1.3	1.4
Soybean meal[b], commercial product	5.8	2.3	5.4	—	2.0	1	1.5
Cottonseed—Globulin, 33% of protein	11.7	3.2	5.4	1.2	3.2	1.1	1.4
Hempseed—Edestin, 50% of protein	15.8	2.2	2.2	3.8	2.3	1.0	1.5
Peanut—Arachin, 60% of protein	12.5	2.1	1.7	0.0	0.6	1.5	0.9
Alfalfa, leaf proteins	7.5	1.4	5.8	—	—	—	—

[a] Data compiled by Almquist unless otherwise indicated.
[b] Data of Block and Bolling.
[*] Determined biologically.

In general, the proteins of meat meals are of somewhat lower feeding value than those of fish meals, since the latter contain smaller proportions of connective tissue. Such tissue tends to be lower in protein value than muscle tissue (Mitchell *et al.* (164)). Inability to utilize the protein may be as important as amino acid composition in causing this low feeding value. It is interesting to note that wool, which in its natural state is highly resistant to peptic and tryptic digestion, was readily used by rats as a protein for growth when finely powdered (208). Similarly, Wagner and Elvehjem (254) found that powdered swine hoof was superior to purified casein as a protein supplement for growing chicks. On the other hand, Slinger *et al.* (224) found that powdered hoofs and horns obtained mostly from steers and cows were slightly inferior to meat meal in chick rations and definitely inferior to fish meal.

Tankage is not recommended for poultry rations. Most tankages contain considerable quantities of blood meal and "stick" which lower their nutritive value. Mussehl (171) found that blood meal fed to growing chicks was decidedly inferior to other animal products. Almquist and co-workers (8) obtained very poor growth when tankage was used in chick rations and Graham *et al.* (85) noted that, when tankage was used in place of either fish scrap or beef scrap in laying rations, both egg production and hatchability decreased considerably. The results of Graham and co-workers, however, were probably complicated by deficiencies of riboflavin in the rations used. Attempts to use urea as a protein supplement (Ackerson *et al.* (6); Bice and Dean (37)) showed that nitrogen of this compound was not utilized by young chicks as a source of protein.

There are contrary reports in the literature regarding the influence of meat products which have developed a high free fatty acid content. Kaupp (131) found that the feeding of fish meals of high free fatty acid content was deleterious to the growth and health of chicks. Te Hennepe (237) reported a decided difference in egg production between a group of birds fed a meat meal containing 19% fat analyzing 23% free fatty acid and another group fed meat meal containing 10% fat of which 7% was free fatty acid. His results, of course, could have been influenced by the difference in the amount of fat in the rations, although it is worth noting that Fangauf and Muller (76) found that meat meals of high fat content had no unfavourable effects when fed to laying hens.

Several investigators (Hunter *et al.* (118); Gutteridge (89); Halpin *et al.* (91); Branion *et al.* (41)) were unable to correlate the acidity of cod liver oil with the growth and livability of chicks, and concluded that fatty acids per se were not responsible for harmful effects which had followed from the use of certain poultry rations.

Schroeder *et al.* (214) observed a decrease in growth and feed consumption and a great increase in mortality when meat scraps high in free fatty acids were included in the ration. However, he attributed his results to an inactivation of vitamin A and to a lesser extent vitamin D by the free acids. On the other hand, Gray and Robinson (87) could find no evidence that very rancid fat had an appreciable effect on the vitamin A content of freshly mixed, well balanced rations. They noted that chicks,

fed on well balanced rations containing meat scraps varying in rancidity and in free fatty acid content (quite comparable in this respect to the meat scraps used by Schroeder *et al.* (214)) showed no significant difference in growth or mortality. It was suggested by Gray and Robinson (87) that deleterious effects observed by other workers may have been due to the presence in the meat products of toxic end products resulting from bacterial action prior to processing.

(b) Fish Meal

The general belief that fish meal is one of the most valuable of the protein supplements used in poultry rations and, in many cases, superior to meat meal is supported by the findings of many workers including, Johnson and Brazie (123), Mussehl (171), Mussehl and Ackerson (173), Arsenjew and Chlebnikow (22), Wiegner and Tscherniak (259, 260), Fangauf and Haensel (77), Robertson *et al.* (203, 204), and Carver *et al.* (63). Almquist *et al.* (9) reported that, unless the fat content is far above the average of 6 to 8%, fish meal, even when fed in large amounts, will give no taste or odour to the eggs or meat of birds to which it is fed. A contradiction to this, in the case of turkeys, will be discussed in a later section of this review.

The value of a fish meal product may depend greatly on the method of its manufacture. Daniel and McCollum (69), Schneider (213), Maynard *et al.* (154), and Maynard and Tunison (155) found that flame dried fish meals were inferior to either vacuum dried or steam dried for promoting growth in rats and concluded that the high temperatures to which the meals were exposed during the flame drying process lowered both the biological value and the digestibility of the proteins. Record *et al.* (194) and Wilgus *et al.* (262) reported similar findings with chickens although it should be mentioned that Cleveland and Fellers (67) could find no evidence that vacuum dried fish meal was superior to the flame dried product for growing chicks.

Meals manufactured from different species of fish or from different parts of the fish may differ considerably in their feeding value. Undoubtedly, fish meals prepared from whole fish or containing a large percentage of the more edible portions, will be of higher value than meals prepared from fish waste. Record and Bethke (193) in a study of the effect of several fish meals on the growth of chicks found that cod and haddock meals were superior to menhaden, shrimp, tuna, salmon, pilchard and crab. Chlebnikow and Arsenjew (65) found herring meal to be superior to cod meal. Asmundson and Biely (23) compared the rate of growth of chicks raised on rations supplemented with pilchard, salmon and halibut meal respectively, and noted that their value varied with the species of fish and the parts of the fish used in their preparation. Sardine meal has been found to give excellent results (Almquist *et al.* (8), Sherwood and Couch (219)), probably because it is manufactured largely from whole sardines. Although Almquist *et al.* (8) found that dogfish meal gave very inferior results in chick rations, later work by Rhian and co-workers (195) indicated that, although dry rendered dogfish meals had little value as

protein feeds for chicks, meals produced by a wet process were equal in quality with fish meals generally used. This is rather surprising in view of the fact that dry rendered meals were found equal to wet rendered meals in protein value by Record *et al.* (194) and even superior by Wilgus *et al.* (262).

(c) Milk Products

Although the present tendency seems to be to evaluate milk products chiefly on their riboflavin content, one should not overlook the importance of the milk proteins. Their high biological value has been discussed by McCollum *et al.* (156). These proteins (85% casein and 14% lactalbumin), while they appear to be somewhat low in arginine and glycine, are particuarly high in trytophane, methionine and lysine (Table 2). Lactalbumin, the chief protein in whey, would appear to be quite as valuable as the combined milk proteins. The value of milk products as animal protein supplements in both chick and laying rations is well attested by the results of many investigators. Roberts and Carrick (199) found that chicks grew equally as well to 10 weeks of age on these rations containing meat and bone scraps and dried skim milk in proportions of 3 : 1, 2 : 2, 1 : 3 respectively. Some workers have found dried milk to be somewhat superior to meat scrap for chick rations (Johnson and Brazie (123)), and for laying rations (Henderson (109)). Paci (183) noted that skim milk could entirely replace meat meal in the diet of chickens. Wiegner and Tscherniak (260), and Weinmuller and Mantel (258), noted that dried skim milk or liquid skim milk were equal or superior to fish meal for stimulating egg production and Bunger *et al.* (48) and Lang (140) reported that liquid skim milk could satisfactorily replace all other protein supplements in the diet of laying hens.

Ott *et al.* (182) added dry skim milk to an all mash ration, formulated to meet all known nutritive requirements, and observed an increase in the rate of growth during the first 2 weeks, total feed consumption and gain in weight during the growing period, feed efficiency during the early part of the growing period, body weight at sexual maturity, and percentage hatchability of the fertile eggs. On the other hand, investigations at the Ontario Agricultural College (85) have shown that, from the standpoint of egg production, powdered buttermilk was somewhat inferior to fish meal. The best results from the standpoint of hatching power of eggs, were obtained when powdered buttermilk was used in combination with beef scrap or fish meal in rations containing cod liver oil.

In general, all the milk products commonly used in chick rations appear to be highly satisfactory as sources of animal protein, and the choice will depend largely on the cost, availability and convenience. Card (61) found that when fed with an all mash basal ration, there was no significant difference in the average weights at 22 weeks of age of pullets which received sour skim milk or fresh butter milk ad libitum, condensed buttermilk fed at the rate of 0.6 pounds to one pound of mash and dried buttermilk fed at the rate of 20% of the mash. Mussehl and Ackerson (172) found that dried buttermilk and dried whey, when fed at the same protein level, were of equal value for chick growth, but that both were some-

what superior to dried skim milk. Roberts (198) found liquid skim milk and condensed buttermilk to be equal or superior to liquid buttermilk when fed with the same mash. Carstens and Prufer (59) observed that buttermilk curd was unsatisfactory for egg production unless supplemented with fish meal. Three types of curds were analyzed by Zimmermann and Malsch (267) and were found to contain substantial amounts of all the essential amino acids except cystine.

Although several workers (88, 75, 167), using rats as experimental animals, reported that exposure to relatively high temperatures reduced the biological value of the milk proteins, there is no evidence that modern methods of preparing milk products impair their protein value for practical poultry feeding. Furthermore, there is no evidence that there is any difference in feeding value between sour and sweet milk when the same protein or solids content of each is maintained. It is possible that high water content of the liquid form of milk products may limit the amount of protein consumed by the bird. If the drinking water supply is restricted, however, the birds should consume sufficient milk. Roberts (198) noted that it was practical to feed a mash containing 10% meal scraps when liquid milk was given as the only drink.

(d) Soybeans and Soybean Oil Meal

The chief protein of soybeans is glycinin which, according to Osborne and Campbell (180) comprises 80 to 90% of the total crude protein of soybeans. The amino acid composition of glycinin has been studied by Osborne and Clapp (181), Csonka and Jones (68), and Baernstein (29). Of more practical use, however, are analyses by Block and Bolling (28) of the mixed protein of the soybean. Their values are given in Table 3. Included for comparison are data for casein compiled by Calvery (57).

TABLE 3.—COMPARISON OF THE AMINO ACID COMPOSITION OF SOYBEAN PROTEIN AND CASEIN

Amino acids	Soybean protein[a]	Milk casein[b]
	%	%
Glycine	0.97[c]	0.5
Arginine	5.8	3.8
Histidine	2.3	2.5
Lysine	5.4	6.0
Tyrosine	4.3	6.6
Tryptophane	1.5	2.2
Phenylalanine	5.4	3.9
Cystine	1.0	0.3
Methionine	2.0	3.4
Threonine	4.0	—
Leucine	6 to 8 }	9.7
Isoleucine	0.4 }	
Valine	4 to 5	7.9
Sulphur	1.1	—

[a] Data of Block and Bolling.
[b] Data compiled by Calvery.
[c] Glycinin Osborne and Clapp.

Cooking the raw soybeans definitely improves the nutritive value of the soybean proteins. Hayward and coworkers (97, 99) and Wilgus *et al.* (264) showed that the application of heat during the preparation of soybean oil meal increased the nutritive value of the soybean and attributed this effect chiefly to an increase in the biological value of the protein. Later work (Hayward *et al.* (101), (98); Gericke and Van der Merwe (83)) suggested the heating process rendered available the sulphur-bearing amino acids, cystine and methionine. According to Almquist *et al.* (18), methionine was the principal limiting factor for the growth of chicks in raw soybeans. They reported that heated soybean protein was slightly deficient in methionine at a 20% protein level but was complete in all other amino acids required by the chick.

The lower nutritive value of the unheated protein may be partly responsible for the rather poor results from the feeding of raw soybeans to chicks and hens. Reports from the Delaware experiment station (Tomhave and Mumford (247, 249)) indicated that ground raw soybeans could not be substituted for any of the buttermilk or more than one-third of meat scraps of a ration without seriously affecting growth, mortality and utilization of feed. Raw soybeans in the diet of pullets tended to reduce egg yield especially when the level in the laying ration exceeded 6.8%. These results could not be attributed entirely to the fat content of the ground soybeans since the decrease in yield following the addition of the extracted oil was less than with the addition of the oil containing bean. Tomhave and Mumford (248) noted, however, that ground soybeans fed at levels up to 10.4% in an all mash laying ration had no detrimental effect on the keeping quality of eggs in storage 4, 6, or 9 months.

In general, more satisfactory results have been obtained with soybean oil meal, during the preparation of which the bean is exposed to a certain amount of heating. As early as 1920, Phillips *et al.* (190) obtained good growth on a ration of corn supplemented with 10% soybean oil meal and minerals. Carver *et al.* (63), however, obtained very poor growth when soybean oil meal was used as the sole protein supplement in poultry rations but showed that it should be used in connection with animal protein concentrates. Ackerson *et al.* (3) found growth was unaffected by replacing ½ of the meat meal and fish meal of a control ration with soybean oil meal. For broiler rations, Roberts and Carrick (201) reported that rapid growth could be obtained and the risk of overfeeding minerals eliminated by replacing part of the meat and bone meal with soybean meal. They obtained excellent results with a ration containing 10% soybean meal, 10% meat and bone scraps and 5% dried skim milk and observed no detrimental effects when the percentage of soybean oil meal was raised to 21%. Irwin and Kempster (120) found an even greater substitution of meat meal and dried buttermilk to be satisfactory, noting that 25% soybean oil meal in combination with 2% animal protein supplements gave gains equal to control rations containing 5% dried buttermilk and 10% meat scrap. However, for most rapid and economical gains, they recommended rations containing somewhat greater proportions of meat scraps or meat scraps and dried buttermilk to soybean oil meal.

The effect of soybean oil meal in the diet of the hen was studied by Wilgus and Gassner (265) who observed that a ration containing 16% soybean oil meal gave poor reproduction. Reduction of the oil meal to 6% and the addition of meat scraps greatly improved the results. Apparently riboflavin and manganese were not responsible for the effects. These workers suggested that the goitrogenic action of soybean which had been observed by several workers might be related to its depressing effect on hatchability. Byerly *et al.* (52) found with pullets that a 20% drop in winter hatchability resulted when soybean oil meal was used as the sole protein concentrate and fed at a level of 20%. However, they obtained satisfactory results when part of the oil meal was replaced with beef scraps. It was later reported by Titus (246) that yearling hens on this same diet showed no drop in winter hatchability. Obviously the age of the birds may play a considerable part in determining the utilization of a particular diet.

For a literature review up to 1938 of the nutritive properties of soybeans the reader is referred to an article by Hayward *et al.* (100).

(e) Cottonseed Meal

Little is known of the amino acid composition of cottonseed meal, since figures are available only for the globulin fraction which comprises about one-third of the total protein (Fontaine *et al.* (79)). Marais and Smuts (149) showed that cottonseed meal was deficient in certain unidentified amino acids and minerals necessary for the growth of rats.

A notorious characteristic of cottonseed is its content of gossypol, an organic substance believed to be toxic. However, there is no evidence to show that cottonseed meal is seriously toxic to chickens, at least, when fed in moderate amounts. Commercial meals are much lower in gossypol than the raw seed. Thornton (243) reported that the cooking process prior to the pressing operation inactivated the gossypol, and Olcott and Fontaine (179) could find no evidence of free gossypol in samples of several commercial meals as measured by the growth of rats. A similar report was made by Hunt (117).

Apparently, however, cottonseed meal does contain certain substances, including small amounts of gossypol, detrimental to egg quality (Lorenz and Almquist (141); Swensen *et al.* (233)) and caution must be used when including the meal in laying rations. Many workers at southern stations (Thompson (242), Walker *et al.* (256), Kempster (132), Sipe (221)) reported that eggs from hens fed varying amounts of cottonseed meal while normal when fresh, developed dark yolks and pink whites on storage. Sherwood (217) noted that eggs laid by hens which received an "all mash" feed containing 9% cottonseed meal did not store well. In a later study, Sherwood (218), showed that only a small percentage of eggs laid by hens, receiving 2 gm. of cottonseed meal daily, deteriorated on 5 months' cold storage, but as the amount increased, the percentage of deterioration increased. He also produced evidence to show that the injurious substance was associated with the oil fraction. Smith (228) found that when cottonseed meal was fed at a level of 2.5%, the storage quality was normal.

However, considerable success has been obtained with cottonseed meal in rations for growing chicks. As early as 1914, Hartwell and Lichtenthaeler (96), found that when mineral supplements were supplied, and the chick limited to the same nitrogen intake, the gains were not very different whether cottonseed meal or beef scraps formed the chief sources of protein.

Mussehl (171) reported that cottonseed meal ranked second to soybean meal as a plant protein supplement for growing chicks, and that, when the protein supplement consisted of equal parts of cottonseed meal and meat and bone meal, growth was satisfactory and only slightly less than that obtained with meat and bone meal as the sole supplement. Reports from Texas (Sherwood and Couch (219, 220), indicated that cottonseed meal was about equal in value to soybean oil meal for growing chicks when fed in combination with animal protein supplements. They found that when vacuum dried fish meal was used to make up 6% of the chick ration, the remaining 12% could be made up of meat and bone scraps, soybean oil meal or cottonseed meal, using 6% of each.

Berry (35) found that a replacement of 10% meat and bone scraps with 10% cottonseed meal, in a ration containing 10% buttermilk, gave somewhat slower and less efficient growth up to 8 weeks and noted that, in the production of broilers, there was no saving by the inclusion of cottonseed meal in the ration. However, from 8 to 24 weeks, in a growing mash containing 10% dried buttermilk, cottonseed meal supplied the added protein just as efficiently as did meat and bone scraps. There was no detrimental effect on the first year's egg production of pullets fed the cottonseed growing ration. Experiments conducted at the South Carolina station (Ringrose and Morgan (197)) indicated that, in a ration with an adequate supply of riboflavin, cottonseed meal could replace up to at least three-quarters of the meat scraps. Growth on this ration did not differ significantly from that obtained on a control containing 19.7% meat scraps (50% protein), 7.5% dried whey and 5% dehydrated alfalfa meal. A small but significant improvement in growth was noted when cottonseed meal replaced about one-quarter of the meat scraps.

Bethke and co-workers (36) compared cottonseed meal and linseed meal and found the former definitely superior. Later work by Ackerson *et al.* (4) substantiated this finding. They replaced cottonseed meal with linseed oil meal as one-third (5% of the ration) of a concentrate in conjunction with meat scraps and fish meal and found that a slightly lower rate of gain (gain in weight divided by the weight of the dry matter fed) was obtained up to 6 weeks. They noted that neither linseed oil meal nor cottonseed meal were as efficient supplements to meat scraps and fish meal as were dried buttermilk or soybean meal. They pointed out that where rapid growth is desired there is some disadvantage in the use of cottonseed meal.

While it is difficult to generalize the above findings, it seems safe to conclude that, with an adequate supply of riboflavin and minerals, satisfactory growth can be maintained when cottonseed meal replaces approximately one-half of the animal protein concentrate or makes up about 10% of the ration.

Some disagreement among investigators as to the relative values of cottonseed meal and other protein supplements can be expected. Apparently, cottonseed meal from different sources and produced by different methods of manufacture may differ greatly in feeding value. Investigations by Olcott and Fontaine (178, 179) showed that the growth promoting value of the protein of cottonseed meal for rats was greatly reduced by autoclaving the meal. The heat treatment caused a marked reduction in the solubility of the nitrogenous constituents in water and in 3% NaCl. Undoubtedly, there is need for improvement in the methods of processing of the meal and for the development of a suitable process for removing the detrimental substances responsible for egg deterioration.

(f) Peanut Meal

Arachin and conarachin are the principal proteins of the peanut, the former making up about 60% of the total protein. Brown (44) gave the following percentage amino acid values for arachin and conarachin respectively: cystine, 1.51, 2.92; methionine, 0.67, 2.12. Early work by Johns and Jones (122) showed a very high arginine content for arachin. Studies by Smuts and coworkers (229, 230, 231), in which rats were the experimental animals, indicated that the proteins of peanut meal had a biological value of 12.5% lower than those of cottonseed meal and were probably deficient in methionine. Beach and White (34) concluded that methionine was the limiting nutritive factor of arachin. This was confirmed by Klose and Almquist (138) who showed that arachin was seriously deficient in methionine but well supplied with cystine. They found that chicks on a ration containing 20% arachin, 5% gelatin and 5% dried yeast required the addition of at least 1% dl-methionine to the ration for satisfactory growth.

In discussing the value of peanut meal in chick rations, Almquist (17) stated "arachin will not support satisfactory chick growth unless lysine, glycine, methionine and tryptophane are added in substantial amounts and it seems that peanut meal cannot be expected to yield good results in chick rations without heavy reinforcements by proteins of animal origin." This statement is substantiated by feeding trials with peanut meal. Bryant (46) found that, in ration containing 5% dried milk, peanut meal supplemented with minerals could be used to replace 50% of the meat meal but that 100% replacements gave much poorer growth. Sherwood and Couch (220) found that the protein of peanut meal was inferior to that of cottonseed meal or soybeam meal as a supplement to animal protein.

For laying rations, Dearstyne, *et al.* (72), found that a ration containing as protein supplements 20% peanut meal and 3% dried milk (scratch grain fed in addition) did not reduce egg production, hatchability or livability of the chicks. Earlier work by King and Cottier (135) also showed that peanut meal when combined with milk was highly satisfactory for laying rations.

(g) Linseed Oil Meal

There is little information available on the amino acid composition of the protein of linseed meal. Marais and Smuts (149, 150) found that the biological value of linseed meal, as measured by feeding experiments with

rats, was increased somewhat by the addition of cystine. Analysis by Hamilton and co-operators (92) also indicated that linseed oil meal was low in cystine and also rather low in lysine.

Rather unpromising results have been reported concerning the use of linseed oil meal in poultry rations. No advantage was found by Christiansen and coworkers (66) from the substitution of 5% of the soybean oil meal in chick rations with linseed oil meal. Bethke and coworkers (36) found that chicks fed on rations containing 10% of linseed oil meal grew slowly and exhibited a marked intestinal disorder and high mortality. Ackerson *et al.* (4) noted that neither linseed oil meal nor cottonseed meal were as efficient as dried buttermilk or soybean oil meal when fed to growing chicks as one-third of the protein concentrate in conjunction with meat scraps and fish meal; cottonseed meal when compared with linseed oil meal gave slightly better gains per unit of feed and nitrogen fed. Similar results were obtained by Sherwood and Couch (220) who found that, in rations containing fish meal, soybean oil meal and cottonseed meal, partial substitution of the soybean oil meal or cotton seed meal with linseed oil meal (2 and 4% of the ration) gave lower gains. Moreover, the grams of feed required to produce a gram of gain was higher.

Experiments conducted by Slinger *et al.* (225) showed that 4.5% of linseed oil meal could not satisfactorily replace its protein equivalent of meat meal in a growing ration. Moreover, the addition of larger amounts of linseed oil meal resulted in an impairment of health and growth so marked that it suggested the presence in linseed oil meal of a "toxic" factor or factors. Further work (226) indicated certain meals contain up to 412 mg. of HCN per kilogram of meal. This is interesting since several workers reported the presence of rather large amounts of cyanophoric compounds in flaxseed and flaxseed oil meal. Villaume and Gillet (253) obtained 240 to 600 mg. of HCN from 1 kilogram of fresh linseed cake. They found this figure to decrease with the age of the cake. Santoro (209) examined samples of flaxseed cakes from several factories and found that all showed strong cyanogenesis. Only one product, however, which yielded on hydrolysis 200-250 mg. HCN per kilogram produced digestive disturbances in cattle.

(h) Distillers' By-products

The residue which remains after the alcohol is distilled from the fermented mash constitutes an important by-product from the distilling industry. This residue consists of solid matter, which contains appreciable amounts of yeast, and a liquid portion which contains various substances in solution.

The feeding value of the by-product varies considerably, depending on the fractions which it includes and the grain from which the mash was prepared. The available literature relating to the value of distillers' by-products used as protein supplements in poultry rations is relatively small. However, it is sufficient to indicate that, while the protein of such products is relatively incomplete, which is not surprising in view of the known

deficiencies of the cereal proteins, it has value when used along with other supplements. D'Ercole *et al.* (73) obtained poor growth with chicks when dried distillers' grains (solid portion of the residue) supplied approximately one-third of the protein of a ration in which the sole animal protein source was 5% dried skim milk. Sloan (227) reported that special distillers' dried grains (residue, following extraction with hexane) when fed in combination with meat scraps, dried skim milk and soybean oil meal satisfactorily comprised 12 to 15% of the total crude protein of a growing ration, but that a 22 or 30% level of special distillers' dried grains fed as the sole protein supplement gave very poor growth.

Using corn distillers' dried grains with solubles (both the solid and liquid residue), Shea *et al* (216) found the protein to be of good supplementary quality for chick rations. When a control ration containing 5% soybean oil meal, 7.5% dried milk, 6% meat scrap and 2.5% fish meal was used and the protein level was kept constant, the dried grains successfully replaced 100% of the dried skim milk or 50% of the soybean oil meal. One-half the dried skim milk and all of the fish meal were also successfully replaced.

Using a similar product in laying ration, Dickens *et al.* (74) found that, provided the protein content was kept constant, all of the dried milk and fish meal or all of the fish meal and part of the meat scraps could be satisfactorily replaced, although hatchability was lessened somewhat.

(i) Hempseed Meal

Edestin is the principal protein of hempseed comprising about 50% of the total protein in the seed. Several workers, including Lugg (142, 143), Bailey (30), Kassel and Brand (130) and Kapeller-Adler (129) have investigated the amino acid composition of edestin. An examination of data compiled by Calvery (57) from the results of various workers reveals that edestin is low in methionine, tryptophane and lysine. Obviously, however, a knowledge of the amino acid composition of only 50% of the total-protein does not permit a very useful evaluation of the amino acid composition of hempseed.

It should be mentioned that heat treatment may be detrimental to the nutritive value of edestin. Waisman and Elvehjem (255) found that edestin autoclaved 5 hours at 120° C. did not produce as good growth in rats as untreated edestin and that the addition of lysine to the autoclaved edestin gave a marked stimulation in growth. Keisel and Kusmin (134) noted that heat caused a decrease in the tyrosine, histidine, tryptophane and arginine content of edestin.

(j) Miscellaneous Vegetable Proteins-Sunflower Seed Oil Meal, Rapeseed Oil Meal, Corn Gluten Feed

Sunflower seed oil meal has long been used as a popular stock feed in Europe, especially for dairy cattle. As far as the author is aware it has not been used extensively as a poultry feed. A few reports, however, are available.

Tabokoff (235) from the results of feeding trials with pullets under Bulgarian conditions found that sunflower oil cake could be used to the extent of 25% of the daily feed with satisfactory results from the standpoint of financial returns from egg production. This conclusion, however, was greatly influenced by the high cost of animal protein concentrates in Bulgaria. Halnan (90) reported that sunflower seeds were a good source of protein and energy for poultry. Experiments, by Pettit *et al.* (189), indicated that satisfactory growth of chicks to 10 weeks could be obtained with a ration containing 10% buttermilk powder and 14% sunflower seed meal. Satisfactory egg production and hatchability were obtained when sunflower seed oil meal replaced all of the soybean oil meal and one-half of the meat meal in a laying mash. Complete data concerning the amino acid composition of the sunflower protein is lacking although Blazowistacheriski and Schubert (39) reported 9.10% arginine, 14.3% histidine, and 1.80% lysine in the globulin fraction of sunflower seed protein.

Rapeseed meal was fed to pullets at a level of 10% of the mash with satisfactory results (78). Pettit *et al.* (189) found that rapeseed oil meal was a satisfactory substitute for meat meal in amounts up to 14% of a chick starter ration but that a 20% level replacing all the meat meal resulted in considerable mortality and a reduction in rate of growth. It has been observed that high levels of rapeseed oil meal fed to cattle have produced serious digestive disturbances, these effects being attributed to the presence of certain glucosides in the rapeseed. Moreover, the meal is somewhat unpalatable and is not liked by the animals. These may be important factors to consider when incorporating rapeseed oil meal into poultry rations.

Some work in the author's laboratory (223) with corn gluten feed (a by-product of the starch industry containing 23 to 25% protein) has shown that, while it is inferior to soybean oil meal as a protein feed, it can satisfactorily replace two-thirds of the meat meal in a chick growing ration and can be fed to layers and breeders.

(k) Methods for Evaluating Protein Supplements on a Numerical Basis

Attempts have been made to supply the poultry industry with information on the relative supplementary value of various protein concentrates when added to the cereal basal diets commonly used in practical poultry rations. In view of the fact that the remarks in section 5 are applicable to most of these studies, it is obvious that the numerical values obtained can provide only rough guides to the relative feeding value of the various protein supplements. Moreover, when ad libitum feeding is practised, relating gain in weight to protein consumed does not give a true measure of protein efficiency. Values so obtained cannot accurately represent biological values of a series of protein feeds since the ratio of gain in weight to protein consumed is positively correlated to the rate of gain itself. Palatability and feed consumption are also complicating factors in ad libitum feeding. It should be stated that the investigators whose work is cited below have for the most part recognized the limitations of the methods which they have proposed.

Two of these methods have been an evaluation of the efficiency of the protein supplements relative to casein. Wilgus, Norris and Heuser (263) determined the percentage N stored by the normal chick during the 7th week of age when fed on a diet containing the supplement under study, divided this by a similar value obtained with a standard casein diet and multiplied by 100. A simple N balance method was employed in which only the total N consumed and the total N excreted were considered. Heiman *et al.* (107) assigned to the various supplements a "gross protein value." This was described as a relative numerical expression of the growth response (gain over control per gm. of supplementary protein consumed) obtained with protein supplements when added to a diet believed complete in all respects except quality and quantity of protein. The test was preceded by a 2-weeks protein depletion period during which a diet containing 8% plant protein was fed. Sufficient of the supplement under test was then added to bring the protein level of the ration up to 11%. All values were reported as relative to casein which was assigned the arbitrary value of 100.

Almquist *et al.* (8, 13) described a chemical method for the estimation of protein quality, i.e., an estimation of the feeding value was arrived at by chemically-differentiated forms of N considered to be of greatest influence on the nutritive value. The protein quality index was calculated from the following formula, the numerical values of which are empirical.

$$\text{P.Q.I.} = A - (B + 0.6C) + 0.4D.$$

where A = % total N precipitated by a copper reagent.

B = % total N not digested by pepsin—HCl.

C = % total N soluble in hot water.

D = % total N precipitated by phosphotungstic acid.

The values as found using this formula correlated well with the nutritive values measured by the growth response of chicks.

One other method may be mentioned here. St. John *et al.* (211) used a modification of Mitchell's formula (162) for the determination of biological value. Their low nitrogen diet analysed 0.042% nitrogen and consisted of starch 63%, sugar 15%, salt mixture 5%, C. L. O. 7%, charcoal 5% and grit 5%. The application of Mitchell's method to poultry involved some difficulty since in birds the urine and feces are not voided separated. Instead of attempting a separation, St. John *et al.* considered that the uric acid and ammonia N represented the urinary N.

6. PROTEIN REQUIREMENT OF TURKEYS

Poults during early growth require a somewhat higher level of protein in their diet than do chicks. Like chicks, however, this requirement is considerably reduced in the later growing periods. Asmundson and Jukes (25) reported results which indicated that the most satisfactory protein levels in the entire ration, from the standpoint of the most rapid and efficient gains, were, 1 to 6 weeks, 24% protein; 7 to 12 weeks, 20% protein;

13 weeks to maturity, a decrease in the protein to about 15%. The experimental findings of other workers (Roberts (202), Hammond and Marsden (95), Headley and Knight (102), Mussehl and Ackerson (269)) are essentially in agreement with these conclusions. There is also evidence (95) that, although live weight gains from about 12 weeks on are not proportional to the protein content of the ration, birds which are heaviest at 12 weeks maintain this advantage to maturity.

There is a suggestion that climatic differences from one locality to another may have quite a marked influence on the nutritive requirements. Robertson and Carver (205) reported from the Washington Experiment Station that increasing the protein level of the concentrate (grain fed in addition) to 39% gave more rapid growth and more efficient utilization of feed. Funk (81), on the other hand, on the basis of a trial in Missouri, claimed that there was no advantage in the use of mashes analyzing higher than 30% protein. It is interesting, in this connection, that Barrett *et al.* (31, 32) and Hammond and Marsden (95), observed that following the first period of most rapid growth, birds fed mashes differing in protein content have a tendency to adjust their protein intake to a common level by varying the ratio of the mash and protein consumption.

While some animal protein in the ration is essential for best results, it appears that a considerable portion of this can be replaced by vegetable protein with no harmful effects. Hunter *et al.* (119) showed that from the standpoint of growth, mortality and food consumption during the first 12 weeks, soybean oil meal or corn gluten meal could satisfactorily replace 50% of any two of dried milk meat scraps or fish meal when these three animal proteins were included in the ration (24% protein) in equal parts. In the subsequent period of 13 to 25 weeks, dried milk and meat scraps were used in the diet in the proportions of 1 to 2 to give a protein level of 16%. It was found that as much as two-thirds of both constituents could be satisfactorily replaced by soya or gluten meal. Funk and Kempster (80) found soybean oil meal superior to either cottonseed meal or corn gluten meal for starting and growing turkeys. All three supplements comprised 10% of the ration. Milby *et al.* (192) reported that linseed meal was not suitable for turkey rations; 10% or more of linseed meal in the ration caused 100% mortality. It has been already noted that similar results have been found with chickens.

It should be mentioned that the inclusion of a large proportion of fish meal in turkey rations may cause objectionable fish flavours and odours in the turkey meat. For this reason it was recommended by Asmundson *et al.* (24), Marble *et al.* (151), Bryant and Stevenson (47) and others that fish oils or fish meal should be omitted from the diet during the few weeks previous to killing. This fishy flavour apparently does not come from the intestines after killing, since removal of the viscera immediately following slaughter did not prevent the taint (Schaible *et al.* (212)).

The practical feeding and management of turkeys have been discussed by Marsden and Lee (153); Traves (252), Taylor (236), Noland (174), Scott (215) and many others.

7. PROTEIN REQUIREMENT OF DUCKS

Only a few reports are available on this subject but it seems evident that ducks grow satisfactorily during the early growth period on a somewhat lower level of protein than do chicks. Horton (27) found that White Pekin ducklings grew more rapidly and ate less food on a ration containing 19% protein than on a ration containing 12%. At 5 weeks of age the birds on the higher protein ration were twice the weight of those on the lower. However, at 15 weeks the weights of the two groups were approximately equal. An examination of the composition of the two rations used by Horton reveals that the protein level was raised by the addition of 5% milk and other ingredients entirely absent from the low protein ration. Thus, other factors in addition to protein level may have influenced his results. Hamyln *et al.* (93), from more extensive experiments, concluded that ducklings make more efficient utilization of protein than do chicks and that the optimum level for growing ducks to 10 weeks is somewhat less than 18%. Their results indicated that a protein level of 25% was approaching an excess and was detrimental to growth. These conclusions were largely confirmed by Roberts (200) who found that a protein level of 17% was as satisfactory as levels of 18 and 20%, the adjustment in protein content being made by varying the amount of meat meal in the ration. The relative value of various protein supplements in duck feeding has not received much attention. There is a suggestion, however, that the duck may not be as critical in its requirements as the chicken. The experiments of Hamyln *et al.* (93) indicated that meat meal was as satisfactory as a mixture of skim milk powder, fish meal and meat meal, when the rations were fed at the same protein level. Roberts (200) observed that a combination of 10% meat scraps and 5% dried milk was superior to 10% meat scrap alone. The percentage of protein, however, was somewhat lower in the latter ration. Investigations in England (MacDonald and Kay (144)) have shown that ducks on grass runs make as satisfactory gains with 10% meat meal as the sole protein supplement as with a combination of meat meal, dried milk and soyabean meal fed at the same protein level. Also from England is a report (Tallent (240)) that fish meal and meat and bone meal gave equal egg production but that the former produced a higher percentage of first grade eggs.

Since nutritive requirements are so closely related to rate of growth it is interesting that Milby *et al.* (159) observed the growth rate of ducks and geese to be almost double that of chickens, turkeys or pheasants during the first few weeks following hatching. However, they also observed that ducks and geese declined in growth rate much more rapidly and at an earlier age (4 to 5 weeks) than the other three species. In view of this, a reduction of the protein level of the duck ration at about 4 weeks might prove more economical than maintaining one level up to 12 weeks or more.

8. PROTEIN REQUIREMENT OF PIGEONS, PHEASANTS, QUAIL

The rearing and feeding of pigeons from a practical standpoint has been discussed by Platt and Dare (191) Mangold and Damkohler (147, 148) and Lee (140a).

As far as is known the pigeon grows more rapidly than any other bird during the first 20 days after hatching. During this period the young squab is nourished on "pigeon milk," a white liquid very high in protein, secreted in the crop of the parent pigeon. Apparently, the pigeon is quite sensitive to the quality of its protein intake. Carr and James (58) on the basis of experiments in which they supplemented a corn and mineral ration with "pigeon milk" suggested that the crop glands may synthesize certain amino acids which are necessary for maintenance and growth. Carter and O'Brien (60) showed that the loss of weight exhibited by pigeons fed solely on polished rice was partly due to inadequate protein intake since supplementing this diet with caseinogen or gluten gave a partial weight recovery.

The young pheasant seems to grow most satisfactorily on a somewhat higher protein level than is suitable for the domestic chicks. Callenbach *et al.* (53) observed that pheasants made the best growth on a diet containing approximately 28% protein. Similar results were obtained by Norris *et al.* (177) who concluded that for early rapid growth pheasants should be given a diet containing 24% protein. Birds on rations containing 15 and 18% protein were markedly retarded in growth and were given to feather pulling and canibalism. Skoglund (222) found that soybean meal supplemented with some low grade meat meal and fish meal formed an ideal substitute for expensive high grade meat meal. He also recommended 65% meat meal as a desirable protein concentrate, observing that because of the high protein requirement of young pheasants the feeding of low protein meat meals gave an excess of minerals and favoured the development of perosis. A similar conclusion in regard to the danger of perosis on certain diets had been drawn earlier by Callenbach and Hiller (54) who recommended the use of meal meat containing 75% protein.

There seems to be very little information recorded in the literature regarding the protein requirements of bobwhite quail. Norris (176) fed protein levels of 21, 24, 27, 30, 33, and 36% to battery reared chicks and showed by these experiments that the bobwhite requires 24 to 27% of protein in its diet for rapid growth.

For a detailed account of the feeding requirements of upland game birds (grouse, quail, pheasants, and wild turkeys) the reader is referred to a discussion by Nestler (128).

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RELATIVE BODY DEPTH AN EXCITING CAUSE FOR DEVELOPMENT OF KEEL BURSAE IN CHICKENS[1]

S. Bird[3]

with

A NOTE ON MEASURING EQUIPMENT[2]

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INTRODUCTION

Investigation of possible causes for the occurrence of disfiguring bursae formations over the ridge of the keel of poultry has been in progress at this laboratory since 1936. Until then solution of this problem had not been attempted and progress was therefore slow during the first five years, after which Hodgson and Gutteridge (4) published the initial report in this field on the principal leads followed to that date. These authors showed that in the main only males of breeds other than Leghorns were susceptible. They found the bursa fluid completely sterile but frequently containing erythrocytes, leucocytes and fibrin, and its protein level varying within the limits characteristic of normal plasma. It was further shown that bursae appear at the earliest about the age of 12 weeks and a little later in late hatched and in slow growing birds. They also found that poorly fleshed specimens were more susceptible than those of better type but did not pursue this lead further. Several physical body measurements were found to be not at all or poorly correlated to bursae incidence, the more important being body weight, circumference of tibia and keel depth as well as roundness of breast. The last mentioned was determined by the angle between the contours of the right and left pectoralis major muscles as measured by an instrument conceived by the present author and described by Gutteridge and O'Neil (3). Various forms of roosts and roosting conditions were found to be without influence on the incidence of bursae with the one exception of continuous roosting on wire netting. One family of Barred Rocks was discovered in which the males seemed to inherit resistance to formation of bursae. O'Neil (5) published a histological description showing these growths to be bursae under the skin and not blisters of the skin, wherefore he rightly proposed the abolition of the term breast blister. The outer area of the bursae walls was found to consist of highly vascular, loose, connective tissue whereas the inner zone largely consists of white fibrous connective tissue which is poorly supplied with blood vessels and therefore undergoes degenerative changes. Later, O'Neil (6) studied the influence of growth on development of bursae. Statements regarding variability as well as final numbers of birds were unfortunately not included in this report and the unavoidably large mechanical errors in the breast angle determinations with our instrument were not taken into account. This author confirmed the statement by

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Hodgson and Gutteridge (vide supra) that late hatched birds generally had a smaller tendency to develop bursae than those of earlier hatches. He also touched upon an important phase of the problem when he stated that "—those birds which grew at a more rapid rate . . . . . had a greater tendency to develop cysts" and "—at the same time . . . . . had sharper breast angles." He did not attempt to draw the basic conclusions as to why the slower rate of growth produces rounder breasts and why, therefore, such birds have less tendency to develop bursae.

Theoretical Considerations

Considering the nature of bursae, as described by the above mentioned authors, the hypothesis seems warranted that their immediate cause is friction or pressure exerted against the keel when a bird is resting in a sitting position. Such aggravating causes presumably would lead to pathologic development of the connective tissue covering the crest of the keel thus protecting the keel from more serious complications involving the periosteum. The picture is in fact somewhat similar to that which in human pathology is popularly known as a case of "housemaid's knee." If this be so, the question arises, why are some birds subject to the degree of aggravation which requires a bursa while others are not. It has been show by Bird (2) that individuals possessing great depth through the pectoral girdle relative to body weight must in fact be sharp breasted, since change in body weight is mainly determined by muscular volume. Inversely even birds which carry a very large volume of flesh but have a characteristically wedge shaped body conformation may be relied upon to show exaggerated depth through the pectoral region, Bird (1). Such birds may in consequence be expected to exert greater pressure on the roost than those of more shallow conformation and thus possess greater need for a protective bursa.

EXPERIMENTAL

The present phase of these investigations has been carried on through the years 1942 and 1943 in which the effects of relative depth and pressure on roost and the influence of these on inherited resistance were studied.

Relative Depth

Deviations from the simple regression curve of depth on body weight adequately describe the relative depth of birds since it was found that all determinations fall on the practically linear segment of the logarithmic curve. Various negative deviations of observed from expected depth will thus denote progressive shallowness while positive deviations will signify greater than expected depth. Depth, from the neural spine of the last cervical vertebra to the anterior point of the sternal crest, was therefore secured by callipers and measured from a millimeter scale. Body weight was measured in grams. Bursa condition of breast was designated as "N" for normal, as "−1" for very slight accumulation of tissue as recognized when lightly manipulated, and definitive bursae as "1", "2", "3", and "4" according to visible size. Barred Rock cockerels numbering 120

were measured at 26 weeks of age in the fall of 1942 and 99 males of the same breed in 1943. The analysis of these measurements is presented in Table 1.

TABLE 1.—SIZE OF BURSAE RELATIVE TO DEPTH OF BIRDS

Type of Bursae*	N	−1	1	2	3	4
1942						
No. birds	80	28	7	2	3	
Mean of observed minus expected depth m.m	− .50	− .75	+1.14	+9.5	+5.67	
1943						
No. birds	51	23	14	7	3	1
Mean of observed minus expected depth m.m	−1.22	− .96	+1.79	+5.71	+2.33	+11.0

* Only bursae above type "1" or 4.2% of all birds handled in 1942 and 11.1% in 1943 were large enough to cause degrading on the market.

In the 1942 analysis the mean square between bursae classes exceeded the error by 2.64 times. In 1943 this value was 2.23. In both years therefore the difference in mean relative depth of the birds in the different classes of bursa size would not occur by chance alone more than once in about 20 trials. However, considerable overlapping did occur between classes from which it is clear that other factors were involved.

Pressure on Roost

Some of these factors were revealed during a test in which it was attempted to measure directly the pressure exerted on the roost by the birds. An electrical pressure gauge was set up by Mr. V. E. Hollinsworth of the Dominion Observatory as shown in Figure 2. On this the birds were made to roost in the dark in positions which assured that only their keels rested on the movable section of the perch. When a bird was made to squat on the roost the indicator of the attached meter would at first record slight pressure with violent oscillations but gradually build up to the characteristic pressure of normal rest. At the same time the oscillations would become the record of the bird's respiration which raises and lowers the pectoral skeleton and thus rhythmically decreases and increases the pressure against the perch. The respiratory rhythm was in most cases between 18 and 30 beats per minute with an occasional bird showing sometimes extremely rapid but still constant rhythmic tempo. Birds with such increase in respiratory rate were nervous and excitable and these would in this manner throughout a night's roosting produce increased friction against the perch and thus presumably more readily acquire a bursa than a more placid bird of like body conformation. There would seem to be small room for doubt that a part of the variability attached to the mean observed minus expected depths of Table 1 was in fact caused by temperamentally induced variation in bursa acquisition.

When the ammeter recorded normal respiration and therefore establishment of normal roosting condition the mean value of repeated oscil-

lations was in each case determined as the characteristic pressure for a bird. The plot of pressure in grams on roost against deviations of observed from expected depth through pectoral girdle is shown in Figure 1.

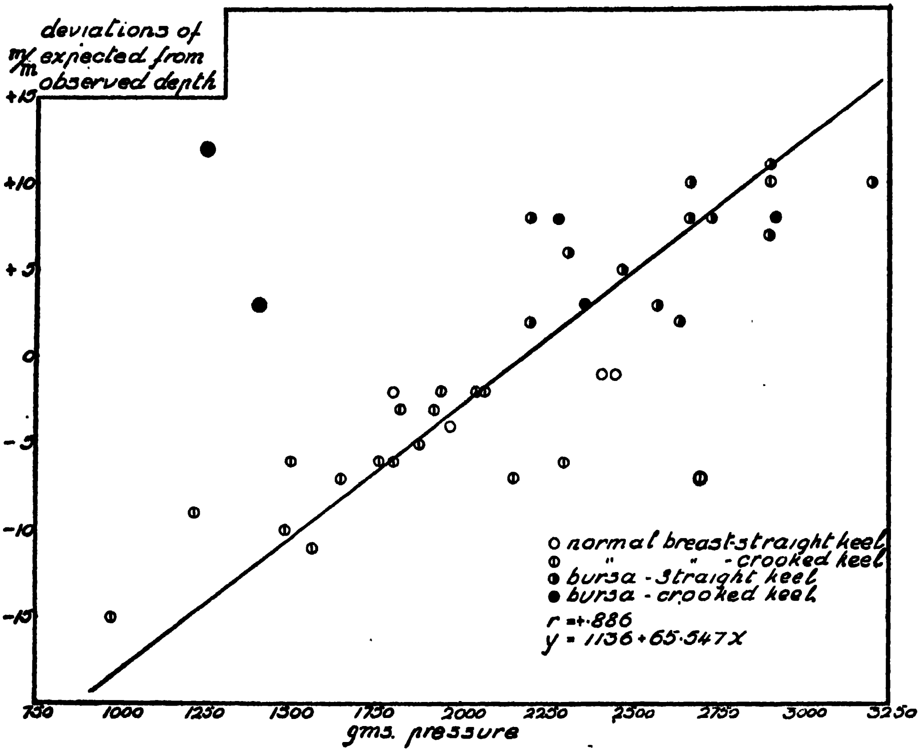

FIGURE 1. Pressure in grams (y) exerted on roost by 39 Barred Plymouth Rock males plotted against the deviations of their observed from expected body depth (χ).

The coefficient of correlation for 36 of the 39 birds tested was $r = +.886$ and the regression of pressure on relative body depth was $y = 1136 + 65.547\chi$. It will be noted that 3 values were outside the normal range of variation. These 3 birds were under such nervous tension that nothing could induce them to roost quietly. Two of these seemed always ready for flight thus pressing but lightly on the roost and the third cowered in fear and so produced abnormally heavy pressure. It is also noteworthy that of 18 relatively deep birds 17 had bursae and of the 22 birds with normal breasts 21 were relatively shallow. Altogether the evidence seems conclusive for the statement that keel bursae are the normal response to pressure, in this case depence against more serious effects from the pressure exerted against the roost by the keel of relatively deep birds.

It should be mentioned in this connection that 67% of the relatively deep birds which formed bursae had straight keels while 81% of the birds which were measured as shallow and were without bursae had crooked keels. It seems probable that misshaping of the cartilaginous keel blade of early life could take place without serious ill effects and so reduce the relative depth of the birds that bursae were not required.

During the last five years the overall incidence of bursae in this flock of Barred Rocks has been recorded each fall when the males were about 24 weeks old. These data are presented in Table 2.

TABLE 2.—INCIDENCE OF BURSAE THROUGH FIVE YEARS

Year	Sires with male progeny	Birds with bursae	From May to September	
			Rain	Sunshine
	no.	%	in.	hr.
1939	12	48.1	18.34	1230
1940	15	40.0	12.13	1127
1941	12	12.9	10.42	1279
1942	18	28.6	16.54	1099
1943	13	41.1	23.25	1132

It will be seen that a formidable variation in bursa incidence has occurred over these years. The impression might therefore easily be gained that this table effectively vitiated the above conclusions with regard to the importance of relative depth of body, since it cannot reasonably be argued that a flock in which several hundred birds are raised each year could change materially in mean depth from one year to another. It should, however, be remembered that the question is not one of absolute depth but of depth relative to body weight and that the latter may very well change abruptly between years depending on the prevailing better or poorer rearing environment. Meteorological phenomena would seem to be important to formation of bursae only to the extent to which they affect rearing conditions. The summary data included in Table 2 might possibly suggest that high rate of precipitation is of detrimental effect. Determination of body depth has not been a routine procedure in our flock and mean relative depth can therefore not be shown for the five years. However, two brothers of the family which has been regarded as genetically resistant to keel bursae were used as sires in the year 1942 and again in 1943. During the first year these males sired a total of 32 sons. In the progeny of each was found one -1 grade bursa or altogether 6.2%. In the second year 34 sons were sired with 9 showing bursae or 26.5%. During the latter year feather condition was excellent but crooked keels were numerous and body weight very inferior. These birds were therefore relatively deep in body with resulting high incidence of bursae. Even birds which generally are non-susceptible may thus develop a need to form bursae if their body conformation is such that this protection is desirable.

Genetic Resistance

Hodgson and Gutteridge (loc cit) showed that bursae appear at the earliest about the age of 12 weeks and that formation of new bursae increases numerically till the age of 18 to 19 weeks in birds growing at average rate. However, under conditions of induced slow rate of growth the appearance of bursae was delayed about two weeks with a lower incidence

than observed under normal conditions. When their Table 4 is recalculated to show the difference between normal and delayed rate of growth Table 3 is evolved.

TABLE 3.—RATE OF NEW BURSAE DEVELOPMENT THROUGH REARING PERIOD

Age in weeks	9-11	12-13	14-15	16-17	18-19	20-21	22	Total %
% Bursae in								
Normal growth 159 birds	.63	4.40	5.03	8.81	12.58	7.55	1.25	40.25
Delayed growth 51 birds	—	1.96	0	3.92	0	11.76	1.96	19.60

Table 3 shows that slow rate of growth to some extent obviates the need for bursae and also causes a delay in their appearance till a later age. This table therefore fully bears out our recorded observations, namely, that a bird must weight at least 1200 gm. before it is capable of exerting the necessary critical pressure against the roost which incites the tissues to develop a protective bursa. It is a well known fact that the skeleton of poultry has a considerably higher growth rate than that which is characteristic of muscular development. Growing birds are therefore relatively thin and sharp breasted till the age of 18 or 19 weeks when the skeleton has virtually completed its growth, whereas muscular development continues till past the age of 40 weeks. Hence the peak in appearance of new bursae at this age when thinness of breast and massive weight combine to create the most aggravating pressure conditions. In slow growing birds the differential growth rates of skeleton and muscle are more nearly similar than in fast growing individuals. Slowly developing birds are therefore relatively plump and therefore relatively shallow with the consequence that in such birds the incidence of bursae is low. Since early in these investigations, it has been appreciated that somewhat slower rate of somatic as well as sexual development is characteristic of the family which until recently has been regarded as having inherited a certain resistance to formation of bursae. However, on the basis of the above mentioned facts the conclusion becomes inevitable that the males of this family are not relatively free from bursae because their connective tissue has developed a specific insensitivity towards this type of development but because their body conformation is of the type that does not need bursae. The character which is genetically controlled in this family therefore may be but low rate of development. This conception would give a logical explanation of the reason why keel bursae are rather recent phenomena and also why they have appeared later under prairie rearing conditions than in the East. Hence, "genetic" resistance should probably be based upon inherited relative shallowness of body since to select for slow rate of growth would be a retrograde step.

Hodgson and Gutteridge and also O'Neil have reported non-susceptibility to bursae formations in Leghorn males as well as in females of all breeds considered. Although the present phase of these investigations was confined to Barred Rock males, a tentative explanation why Leghorn males do not need the formation of protective bursae may nevertheless be

deduced from other data in our files. In the spring of 1939, 50 Rock and 65 Leghorn males were weighed and measured every third week from the age of 8 weeks. The mean weight and depth of body for these populations are presented in Table 4.

TABLE 4.—MEAN WEIGHT AND DEPTH OF BODY

Age in weeks	50 Barred Rock males		65 White Leghorn males	
	χ weight	y depth	χ weight	y depth
	gm.	m.m.	gm.	m.m.
8	653.3	84.7	609.3	79.2
11	990.4	103.9	869.7	97.4
14	1401.9	114.9	1139.0	103.1
17	1843.8	123.8	1431.5	110.3
20	2259.0	133.0	1617.3	115.5

It will be seen that at 14 weeks of age the Rocks had acquired sufficient weight, which, given a suitable body conformation, might produce the pressure that requires a bursa whereas the Leghorns attained this weight three weeks later. The regression of depth on weight of the Rocks was $y = 86.32 + 0.020444\chi$. When in this equation the mean weight of the Leghorns at 17 weeks is substituted for χ the value of y becomes 115.6 m.m. expected relative depth. The observed mean depth for Leghorns at this age was 110.3 and these birds therefore are 5.3 m.m. shallower relative to body weight than comparable Rock males. From Table 1 it may be seen that birds which do not require bursae are on the average 1.22 m.m. shallower than expected and it can therefore probably be assumed that due to their much greater relative shallowness Leghorn males do not develop the pressure against the roosts which requires a protective bursa. Thus the body conformation which is desirable in Barred Plymouth Rocks already exists in Leghorns. Although data on females have not been obtained at any time during our work it is but a matter of common observation that females at all times are rounder in the breast than males. As roundness of breast in most cases is dependent on relative shallowness it is presumably safe to say that females are at least as shallow relative to their body weight as are Leghorn males and females in general will presumably therefore not be in need of bursae formations.

SUMMARY AND CONCLUSIONS

It has been found that the incidence and severity of keel bursae in fowl is largely dependent on the magnitude of their depth through the pectoral region relative to body weight and that the weight of pressure which the keel of a bird exerts against the perch during roosting is highly correlated to its relative body depth.

Crooked keels presumably decrease the incidence and severity of keel bursae by reducing the relative depth of the bird.

Variations in bursae incidence from year to year, which cannot be due to changes in mean body depth in a flock, may be due to the other component of relative depth, namely, body weight, as this can easily change materially between years depending on rearing conditions.

Supporting data have been presented which indicate that the non-occurrence of bursae in White Leghorn males and in females is consistent with the thesis for bursae formation as developed herein.

From these data it is therefore concluded that keel bursae afford a beneficient protection against more serious injury which otherwise might result from the pressure exerted by the keel of relatively deep birds against the perch during roosting, and that freedom from bursae in rapidly growing birds can only be expected in families of inherited relative shallowness of body.

ACKNOWLEDGMENT

Thanks is extended to the Dominion Astronomer, Dr. R Meldrum Stewart for assistance afforded by a member of his staff and for loan of instruments, and to Mr. H. S. Gutteridge of this Division for ratings of bursa conditions on all birds.

NOTE ON MEASURING EQUIPMENT

In order to determine the total pressure that a bird exerts through the keel of its breast bone when roosting, special measuring equipment was required. This is illustrated in the accompanying photograph Figure 2 and is described briefly as follows:—

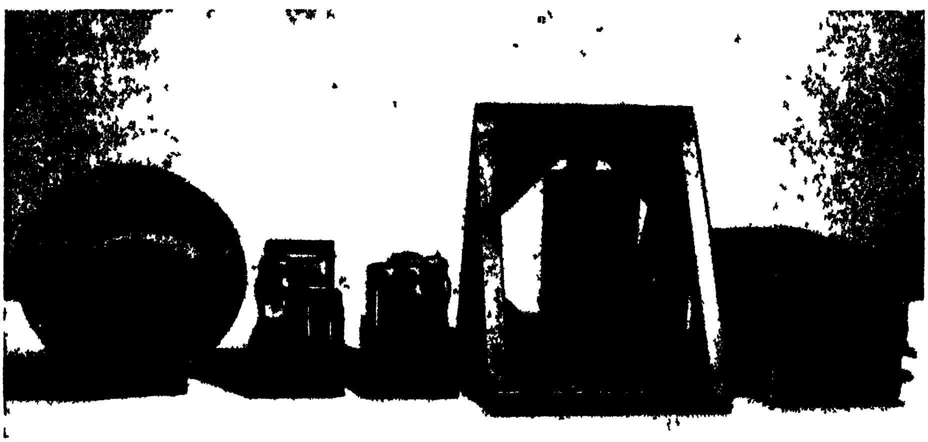

FIGURE 2. Measuring equipment.

A perch was constructed having a cut out mid section, 1 inch in width, which was fixed to a sensitive gauging head and adjusted to float in the gap from which it was cut. By means of a vacuum tube amplifier and associated voltage stabilizers, accurate readings of displacement, due to pressure on the gauging member, were obtained on the attached ammeter.

A calibration curve for the meter was made by balancing standard gram weights in increasing values on the floating member. By adjusting the magnetic poles in the gauge head an expanded scale was obtained, the range being from a minimum of 900 gm. to a maximum of 3500 gm. which proved sufficient to accommodate all birds tested.

While the measuring apparatus appears to be somewhat elaborate, it nevertheless proved ideal for the purpose. Other devices considered required considerable motion of the floating block to give an indication. This was not permissible since displacement of the block relative to the perch would cause relief of the pressure which it was desired to measure. In the gauging head shown the motion necessary for full scale reading was only a few hundredths of an inch.

Other attributes desired in the measuring device were ability to withstand suddenly applied loads, freedom from noise, restriction of lateral motion to avoid friction between block and perch, a remote indicator which could be located where light was available, and a minimum of operating adjustment, since both hands would be required for accurately placing the birds on the perch in such positions that their keels rested on the floating block only avoiding contact with the fixed perch.

The equipment used met all the above conditions. Although it was originally constructed for another purpose it was readily adapted to this project.

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RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

These publications are available from Central Sales Branch, Imperial Agricultural Bureaux, Penglais, Aberystwyth, Great Britain.

MINERALS IN PASTURE DEFICIENCIES AND EXCESSES IN RELATION TO ANIMAL HEALTH. Technical Communication No. 15. By F. C. Russell, Imperial Bureau of Animal Nutrition. Price 5 shillings.

Pasture is the natural food of cattle, sheep and horses. It is the sole food of the majority of cattle and sheep in the world. Even under intensive methods of production where fodder crops and concentrates are fed, these are, on the whole, merely supplementary to pasture either grazed or in the form of hay, grass silage or dried grass. Pasture is thus the main raw material of milk, meat, mutton, wool, hides and other products of the herbivora. With the possible exception of cereals, it is the most important world crop, and, indeed, the misguided exploitation of large

areas of land by cropping continuously with cereals has resulted in the major problem of soil erosion, the formation of wasting sores on the land surface that can best be healed by re-establishing pasture. Pasture is, therefore, of great economic importance, and undoubtedly this importance will tend to increase in the future.

A large amount of work has been done on "deficiency diseases." It has been found that mineral deficiencies in pasture are more important than vitamin deficiencies. If the pasture contains all the inorganic nutrients needed for health and is sufficient in quantity, there is unlikely to be a deficiency of either vitamins or protein.

It became obvious some years ago, that the great volume of literature which has appeared in recent years called for a new review of the literature on minerals in pastures. Miss Russell of the Imperial Bureau of Animal Nutrition was given the task and this publication is the result. Only those who have compiled and written such reviews appreciate the amount of laborious work needed to bring together all the available information from the many hundreds of papers published and arrange it in a logical and lucid form. Miss Russell has performed a service for which research workers in this field will be grateful. (From a foreword by Dr. J. B. Orr).

ALTERNATE HUSBANDRY. Imperial Agricultural Bureaux Joint Publication No. 6. Price 5 shillings.

In view of the fact that the term "alternate husbandry" has been widely used in agricultural literature for many years, it is first necessary to define the practice with reference to modern agricultural thought and to the discussion that follows in this publication. In this more restricted sense, alternate husbandry means a planned and regular (and yet at the same time flexible) alternation on every field of a farm or other agricultural unit of a period of arable husbandry (for the production of crops for human consumption, industry, or animal fodder) with a period of direct animal use, in which the composition of the herbage or forage mixture is so adjusted as to provide a maximum amount of fodder of the proper type and at the proper time for the animal crop that is to be produced, and at the same time so as to provide for the maintenance of an optimal state of fertility or productivity in the soil throughout the whole course of the rotation.

This publication of 156 pages has the following chapters:—

1. *Trends in Different Countries and Regions* by *R. O. Whyte.*
2. *The Influence of Herbage Rotations on the Soil* by *G. V. Jacks.*
3. *The Roots of Herbage Plants* by *R. O. Whyte.*
4. *Types of Leys and Their Component Species* by *R. O. Whyte.*
5. *The Animal Crop in Relation to Alternate Husbandry* by *J. E. Nichols.*
6. *Fertility Types, Production and Requirements* by *R. O. Whyte.*
7. *Alternate Husbandry and Current Agricultural Problems* by *R. O. Whyte.*
8. *Alternate Husbandry and Animal Diseases* by *E. L. Taylor.*
9. *Economic Factors in Changes from Other Agricultural and Pastoral Systems to Alternate Husbandry* by *A. W. Ashby and W. J. Thomas.*
10. *Bibliography.*

IMPERATE CYLINDRICA: Taxonomy, Distribution, Economic Significance and Control. Imperial Agricultural Bureaux. Joint Publication No. 7. Price 2s. 6d.

Imperata cylindrica is a grass species that is widely distributed in tropical and subtropical lands, especially in open country, on abandoned cultivated land and in deforested areas, where it may be the chief ground cover for many miles. It is one of the most common grasses in Africa, stretching from the tropics southwards to the Union of South Africa and northwards to the shores of the Mediterranean. It is also found in southern Europe and eastwards to Turkestan and Afghanistan, and is well known in India, Malaya, China, Japan and Australia.

This publication gives full taxonomic descriptions of the five varieties that are recognized within the species, *Imperata cylindrica*, and outlines the geographical distribution of each.

The effects of *I. cylindrica* on economic crops are generally adverse, and only in a few cases favourable; crops affected include quinine, tea, rubber, teak, fig, coconut, oil palms, sal, and abaca. The grazing and fodder value of *I. cylindrica* has been tested in a number of tropical and subtropical countries; the general conclusion seems to be that, although the grass does provide animal fodder in certain types of less advanced agriculture, it will ultimately be replaced by superior species managed according to modern methods. Other ways in which *I. cylindrica* can be used with varying success include thatching, paper-making, and soil conservation.

POTATO COLLECTING EXPEDITIONS IN MEXICO AND SOUTH AMERICA. II.—Systematic Classification of the Collections. By J. G. Hawkes. Imperial Bureau of Plant Breeding and Genetics. Price 7s. 6d.

The potato collecting expeditions in Mexico and South America, sent out by the Imperial Agricultural Bureaux, represent perhaps the first attempt within the British Empire to make a thoroughly scientific and exhaustive collection of indigenous plant material for the initiation of a large-scale breeding program. Unlike expeditions sent out by other countries in the past, the energies of the collectors were directed wholly towards the problem of potatoes, since no attempt was made to collect samples of food plants in general. This concentration of efforts enabled a very large and detailed collection of over 1,000 specimens to be made. Samples were obtained from the whole length of the Andes mountains, not only in the more populous and easily accessible regions, but also in the wildest places far from human habitation, where no expeditions had collected previously.

The present work represents the results of nearly three years' study of the taxonomy and systematic classification of the Empire Potato Collection, using as a basis chiefly geographical, morphological and cytological criteria. In the U.S.S.R., Vavilov's complex taxonomic method was applied with signal success in elucidating the systematic relationships of

the potatoes collected by the Russian expeditions. Use was made, not only of the three criteria mentioned above, but also of genetical, biochemical and physiological data. For reasons already mentioned, it was not possible to employ all these methods in the present study; nevertheless the author ventures to believe that it is fairly complete in its essentials and will not need substantial alteration when the results of the tests for disease and frost resistance and for protein and vitamin-C content become available.

In order to clarify the subject of potato taxonomy, rather more than was necessary for a bare catalogue of the species encountered by the collectors has been included in the present work. There is indubitably a great need for a comprehensive treatise on potato taxonomy, especially on the problem of the wild species, which are described in scores of different periodicals in nearly every European language; moreover these publications are often inaccessible to both plant breeder and botanist. The present Bulletin cannot attempt to present a monographic treatment of the subject, since it would be rendered too cumbersome thereby. An outline of our present knowledge on the phylogeny and systematic relationships of wild and cultivated potatoes has, however, been embodied.

BIBLIOGRAPHY ON INSECT PEST RESISTANCE IN PLANTS (with a Supplement on Resistance to Nematodes). Imperial Bureau of Plant Breeding and Genetics. Price 1s. 6d.

As plant breeding and genetics progress and the general standard of crop production and quality rises, the question of selection of types for their resistance to damage by insect pests advances more and more in the foreground in any program for the improvement of agricultural crops and other economic plants.

The sources drawn upon include publications from the British Commonwealth, the main European countries, U.S.A., various South American countries, U.S.S.R. and Japan. The bibliography with its supplement contains over 550 references, which are arranged according to subject.

A NEW JOURNAL

PROCEEDINGS OF THE NUTRITION SOCIETY. Published by W. Heffer & Sons Limited, Cambridge, England. Price per volume (including 2 double numbers) 25s. Price of double numbers singly 15s.

This publication includes papers presented before the English and Scottish groups of *The Nutrition Society*. This organization was founded in 1941 for the purpose of the discussion and publication of papers presented by workers studying different aspects of the same problem in agricultural and medical institutions. The first issue (Vol. 1, Nos. 1 and 2), contains papers on: The Evaluation of Nutritional Status; Food Production and Distribution; Food Supplies in Relation to Human Needs (1) Requirements for Health and (2) Requirements in Terms of Food; Problems of Collective Feeding in War Time. The papers are by a number of leading English and Scottish workers.